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ABSTRACT

A guide for advancement and training in the Instrumentman 1 and C ratings for Navy personnel is provided in this manual. The chapters outline the duties and responsibilities of the Instrumentmen involved with mechanical instrument repair and calibration shops, safety procedures, watch and clock repair and adjustments, electrical typewriters, calculators, other office equipment, manufacturing and administrative duties. There are extensive diagrams, drawings, and photographs together with an appendix containing a report of calibration for the Deadweight Tester. (KP)

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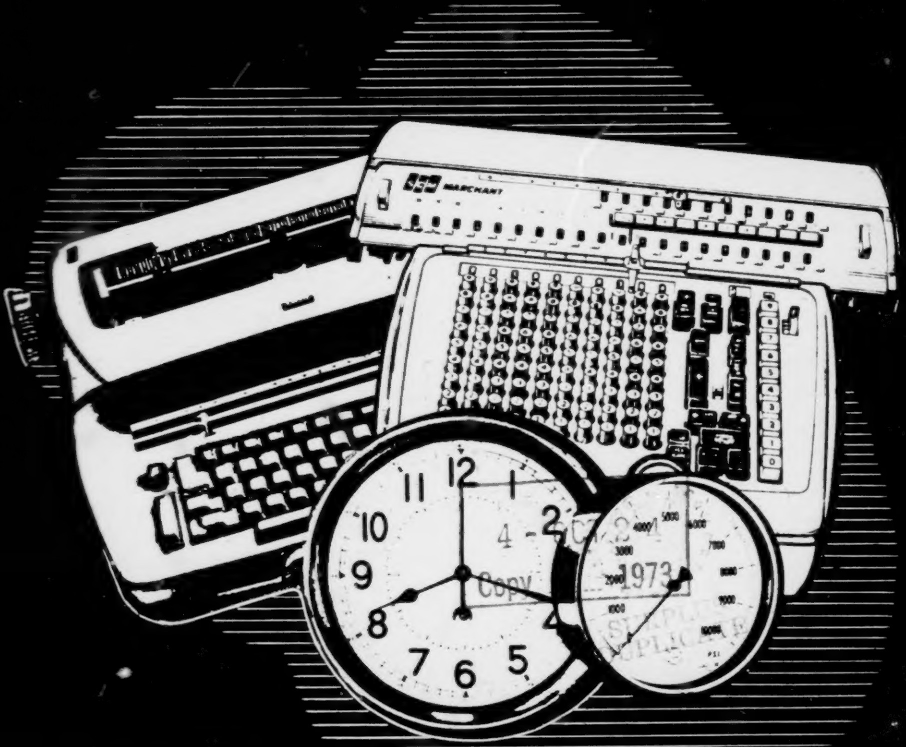

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INSTRUMENTMAN 1 & C

NAVAL TRAINING COMMAND

RATE TRAINING MANUAL NAVTRA 10194-C

ED 082020

PREFACE

The primary purpose of training is to produce a Navy which can maintain control of the sea and guarantee victory. Victory at sea depends upon the state of readiness of shipboard personnel to perform tasks assigned to them in accordance with the needs of their ship. This Rate Training Manual provides information related to the tasks assigned to Instrumentmen First Class and Chief Instrumentmen who maintain office machines, watches, clocks, gages, torque wrenches, flow meters, temperature measuring devices, and other instruments. It is only when shipboard personnel can and do perform their tasks efficiently that each ship will be adding her contribution which is essential to guarantee victory at sea. As an IM1 or IMC, you will be expected to know the information in this manual and to perform your assigned tasks. The degree of sucess of the Navy will depend in part on your ability and the manner in which you perform your duties.

This manual was prepared by the Naval Training Publications Detachment, Washington, D. C. for the Naval Training Command. Technical assistance was provided by Naval Ships Engineering Center, Philadelphia; Naval Ship Systems Command, Washington, D. C.; Service School Command, Great Lakes.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

INTRODUCTION

At this stage in your naval career, you must be aware of how important training is to the accomplishment of your own goals and the Navy's mission. Neither objective can be attained unless you continue to acquire the specific knowledges and skills for doing, or doing better, your assigned tasks. When combined with practical experience, the instruction provided by this Rate Training Manual will help you become a proficient worker, and enable you to accept greater responsibilities. The Navy, too, will benefit from your technical competence and sense of personal responsibility.

Your own contribution to "victory at sea" depends largely on your willingness and ability to accept increasing responsibilities. When you became a Third Class Instrumentman you began to accept a certain amount of responsibility for the work of others. Advancement to Second Class meant more responsibility. By studying this manual, you indicate a desire to take on even more.

With each advancement, you acquire increased responsibility not only in matters relating to the occupational requirements of your rating, but in military matters as well. You will find that your responsibilities for military leadership are about the same as those of petty officers in other ratings, since every petty officer is a military person as well as a technical specialist. Your responsibilities for technical leadership are special to your rating and are directly related to the nature of your work. Maintaining mechanical instruments, office machines, and Navy timepieces calls for teamwork, and requires a special kind of supervisory ability that can only be developed by personnel who have a high degree of technical competence and a deep sense of personal responsibility.

YOUR RESPONSIBILITIES WILL EXTEND BOTH UPWARD AND DOWNWARD. Both officers and enlisted personnel will expect you to translate the general orders given by officers into detailed, practical on-the-job language that can be understood and followed even by relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their work properly. At the same time, you must be able to explain to officers any important needs or problems of the enlisted men.

YOU WILL HAVE REGULAR AND CONTINUING RESPONSIBILITIES FOR TRAINING. Even if you are lucky enough to have highly skilled and well trained men in the optical shop, you will still find that more training is necessary. Some of your best workers may be transferred and inexperienced or poorly trained personnel may be assigned to you. Or a particular job may call for skills that none of your personnel have. These and similar problems require you to be a specialist who can train others to perform their assigned tasks.

YOU WILL HAVE INCREASING RESPONSIBILITIES FOR WORKING WITH OTHERS. You will find that many of your plans and decisions affect a large number of people, some of whom are not in the Instrument workcenter and some of whom are not even in the same division. It becomes increasingly important, therefore, to understand the duties and responsibilities of personnel in other ratings. Every petty officer in the Navy is a technical specialist in his own field. Learn as much as you can about the work of other ratings, and plan your own work so that it will fit in with the overall mission of the organization.

AS YOUR RESPONSIBILITIES INCREASE, YOUR ABILITY TO COMMUNICATE CLEARLY AND EFFECTIVELY MUST ALSO INCREASE. The basic requirement for effective communication is a knowledge of your own language. Use correct language in speaking and in writing. Remember that the basic purpose of all communication is understanding. To lead, supervise, and train others, you must be able to speak and write in such a way that others can understand exactly what you mean.

A second requirement for effective communication in the Navy is a sound knowledge of the Navy way of saying things. Some Navy terms have been standardized for the purpose of ensuring efficient communication. When a situation calls for the use of standard Navy terminology, use it.

Still another requirement of effective communication is precision in the use of technical terms. A command of the technical language of the Instrumentman rating will enable you to receive and convey information accurately and to exchange ideas with others. A person who does not understand the precise meaning of terms in connection with the work of his own rating is at a disadvantage when he tries to read official publications relating to his work. He is also at a great disadvantage when he takes the written examinations for advancement. Although it is always important for you to use technical terms correctly, it is particularly important when you are dealing with lower rated men; sloppiness in the use of technical terms is likely to be very confusing to an inexperienced man.

YOU WILL HAVE INCREASED RESPONSIBILITIES FOR KEEPING UP WITH NEW DEVELOPMENTS. Practically everything in the Navy—policies, procedures, equipment, publications, systems—is subject to change and development. As an IM1, and even more as an IMC, you must keep yourself informed about all changes and new developments that might affect your rating or your work.

Some changes will be called directly to your attention, but others you will have to look for. Try to develop a special kind of alertness for new information. Keep up to date on all available sources of technical information. Information on sources of primary concern to the Instrumentman is given later in this chapter.

YOUR JOB

An Instrumentman is generally assigned duty in the Instrument workcenter on repair ships and tenders. Here he will maintain the office machines, Navy timepieces, and mechanical instruments. A senior Instrumentman will have administrative duties to perform, such as preparing or helping his division officer prepare preventive maintenance schedules in accordance with the Planned Maintenance Subsystem of the 3-M System; maintaining records of receipt and expenditure for repair parts and supplies; planning, scheduling, assigning, and releasing repair work in accordance with ship's availabilities; and supervising the training of personnel in repair and overhaul of office machines and other instruments.

Shore duty for Chief and First Class Instrumentmen includes recruiting duty and instructor duty at an OM/IM school or Naval Reserve training center. Also, there are billets for Chief Instrumentmen at the Naval Examining Center, Great Lakes, Illinois, where the Navywide advancement examinations are constructed, and at the Naval Training Publications Detachment, where Rate Training Manuals, correspondence courses, and other training materials are written and revised.

SCOPE OF THIS TRAINING MANUAL

Before studying this manual, you should know its scope and purpose. Go over the table of contents and note the arrangement of topics. Subject matter can be organized and presented in many different ways. You will find it helpful to get an overall view of this manual's organization before starting to study. Here are some points of interest concerning this manual:

- It must be satisfactorily completed before you can advance to IM1 or IMC, whether you are in the Regular Navy or in the Naval Reserve.

- It is designed to provide information on the occupational qualifications for advancement to IM1 and IMC.

- The occupational qualifications that were used as a guide in the preparation of this manual were those promulgated in the Manual of Qualifications for Advancement, NAVPERS 18068-C (1971). Changes in the Instrumentman's qualifications occurring after this edition of the Quals Manual became effective may not be reflected in the topics of this training manual.

- It includes subject matter that is related to both the KNOWLEDGE FACTORS and the PRACTICAL FACTORS of the qualifications for advancement to IM1 and IMC. No training manual, however, can take the place of on-the-job experience for developing skill in the practical factors. When possible, this manual should be used in conjunction with the Record of Practical Factors, NAVPERS 1414/1.

- It is NOT designed to provide information on the military requirements for petty officers. Such information is contained in specially prepared Rate Training Manuals, which are described briefly later in this chapter.

SOURCES OF INFORMATION

It is very important for you to have an extensive knowledge of the references to consult for detailed, authoritative, up-to-date information on all subjects related to the military requirements and to the occupational qualifications of the Instrumentman rating.

Some of the references are changed or revised at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been entered.

NAVAL TRAINING (NAVTRA) PUBLICATIONS

Effective 15 January 1972, the Naval Training Support Command and its field activities came directly under the command of the Chief of Naval Training instead of the Chief of Naval Personnel. Training materials published by the Naval Training Support Command after the above date are designated NAVTRA in lieu of NAVPERS; in most cases, the numbers remain as originally assigned. The designators of publications printed before the above date will be changed as each publication is revised.

The naval training publications described here include some that are absolutely essential for meeting your job requirements and some that are extremely helpful, although not essential.

Bibliography for Advancement Study, NAVTRA 10052

This pamphlet provides a working list of material for enlisted personnel who are studying for their advancement examinations. It is revised and issued annually by the Naval Training Support Command. Each revised edition is identified by a letter following the NAVTRA number. When using the bibliography, be sure you have the most recent edition.

The working list contains required and recommended Rate Training Manuals and other references. A Rate Training Manual marked with an asterisk (*) in NAVTRA 10052 is MANDATORY at the indicated rate level. You are responsible, however, for all references at lower levels, as well as those listed for the rate to which you are seeking advancement. A mandatory Rate Training Manual may be completed by (1) passing the appropriate correspondence course based on the manual, (2) passing locally prepared tests based on the manual, or (3) in some cases, successfully completing an appropriate Navy school.

All references, whether mandatory or recommended, listed in NAVTRA 10052 may be used as source material for the written advancement examinations, at the appropriate levels. In addition, references cited in a mandatory or recommended Rate Training Manual may be used as source material for the examination questions. Figure 1-1 is a modified sample page of the bibliography. It does not show all the references listed in NAVTRA 10052 for the IM rating.

Rate Training Manuals

These manuals help enlisted personnel fulfill their job requirements as expressed by the practical and knowledge factors that they must acquire for advancement. Some manuals are general, and intended for more than one rating; others, such as this one, are specific to the particular rating.

Rate Training Manuals are revised from time to time to bring them up to date. The revision of a Rate Training Manual is identified by a letter following the NAVTRA number. You can tell whether a Rate Training Manual is the latest edition by checking the NAVTRA number and the letter following the number in the most recent edition of the List of Training Manuals and Correspondence Courses, NAVTRA 10061 (revised).

The current editions of Basic Military Requirements, NAVPERS 10054, Military Requirements for Petty Officer 3&2, NAVPERS 10056, and Military Requirements for Petty Officer 1&C, NAVPERS 10057, provide information mostly on general military subjects. The manuals also contain information on the enlisted rating structure; how to prepare for advancement; how to supervise, train, and lead other men; and how to meet your increasing responsibilities.

The basic training manuals — Tools and Their Uses, Blueprint Reading and Sketching, and Basic

RATINGS (1)	PUBLICATIONS TITLES (2)	TEXT IDENTIFICATION NUMBER (3)	CORRESPONDENCE COURSE IDENTIFICATION NUMBER (4)	APPLICABLE RATE LEVELS (5)
GROUP IV. PRECISION EQUIPMENT				
INSTRUMENTMAN (IM)	*Instrumentman 3 & 2	NavPers 10193-C	91383-1	E-4, E-5
	*Instrumentman 1 & C	NavPers 10194-B	91385-B	E-6, E-7
	Blueprint Reading and Sketching (Chapters 1-3)	NavPers 10077-C		E-4
	Opticalman 3 & 2 (Chapter 7-material on cleaning and painting)	NavPers 10205-A		E-4
	Tools and Their Uses	NavPers 10085-B	91228-2	E-4
	Supply Afloat Packaging Procedures	NavSo P-484		E-4
	Basic Machines (Chapters 1, 3, 4, 6, 9, 10,11)	NavPers 10624-A	91230-F	E-4
	Mil Std 1330 (Ships)			E-4
	Fluid Power (Chapters 1, 2, 3, 9, 10)	NavPers 16193-B		E-4
	Maintenance and Material Management (3-M) Manual (Chaps. 1, 2, 3, 4, 6) (Chaps. 5, 7)	OpNav 43P2		E-5 E-6
	Boilerman 3 & 2 (pp 134-139)	NavPers 10535-1		E-6
	Basic Electricity Chapter 2 Chapter 4	NavPers 10086-B		E-4 E-5

Figure 1-1.—Sample bibliography (IM).

91.576.1

RATINGS (1)	PUBLICATIONS TITLES (2)	TEXT IDENTIFICATION NUMBER (3)	CORRESPONDENCE COURSE IDENTIFICATION NUMBER (4)	APPLICABLE RATE LEVELS (5)
GROUP IV. PRECISION EQUIPMENT—Continued				
INSTRUMENTMAN (IM) (Continued)	Navy Security Manual: (Articles 0601-0605, 0610-0614, 0616-0619, 0622-0623, 0801-0803, 0808, 0811.1, 0901-0902, 0910, 0915, 0925.1, 1206, 1504, 1515-1516, 1519)	OpNavInst 5510 series		E-4
	(Articles 0105, 0107, 0112; Chap. 5; Chap. 6, sec. 5; 0701, 0704)			E-5
	(Articles 0405-0406, 0423-0424, 0426, 0432, 0443)			E-6
	(Chap. 3)			E-7
	NavShips Technical Manual (Chapter 9230)			E-4
	(Chapters 9690, 9870)			E-6
	Physical Measurements	NavAir 17-35QAL-2		E-6
	Boilerman 1 & C (Chap. 6)	NavPers 10536-D		E-7
	Opticalman 3 & 2	NavPers 10205-A	91386-A	E-8
	Handbook of Test Methods and Practices (Secs. 1; 2, pars. 2-1, 2-2 and 2-11)	NavShips 0967-000-0130		E-8

91.576.2

Figure 1-1. — Sample bibliography (IM) — Continued.

Electricity—are available for the use of all rates and ratings, as [illegible]. Their use by Instrumentmen is essential.

For a complete listing of Rate Training Manuals, consult the List of Training Manuals and Correspondence Courses, NAVTRA 10061 (revised).

Correspondence Courses

Naval correspondence courses are self-study media for providing instruction to personnel in professional naval subjects. They play an important role in helping enlisted personnel train for advancement and in meeting their job requirements. Enlisted personnel may enroll in three kinds of correspondence courses: Enlisted (ECC), Officer-Enlisted (OCC-ECC), and a combination of the ECC and the functional individual training system (ECC-FITS). There is an ECC based on this Rate Training Manual.

TRAINING FILMS

Training films are valuable sources of information on many technical subjects. The United States Navy Film Catalog, NAVAIR 10-1-777, lists titles and descriptions of films which have been authorized for training and information in the Naval Establishment. This catalog also contains instructions on how to obtain film prints. Catalog supplements are published periodically to provide new listings and corrections.

When selecting a film, be sure to note its year of production which is given in the catalog. Procedures sometimes change rapidly, thus some films become obsolete rapidly. If obsolete only in part, a film may be shown effectively if before or during its showing you point out to trainees the parts that have changed.

CHAPTER 2

ADMINISTRATION

As an Instrumentman First or Chief you will take on the administrative duties and responsibilities that go with the third stripe or the "hat". These include inspections, maintaining logs and records, inventories, ordering spare parts, and preparing training schedules.

To successfully perform your job, you need a thorough understanding of department and division organization and administration aboard your ship. You will also need to know how your work center is organized and administered.

This chapter describes the organization and functions of a representative tender repair department, points out the duties and responsibilities of department personnel, and provides some techniques for supervising an instrument shop. After you have read this chapter, you should be able to:

a. Outline the organization of a repair department and state the functions of its personnel.
b. Schedule and assign repair jobs.
c. Prepare appropriate forms.
d. Outline quality control procedures.
e. Prepare training plans for personnel.
f. Describe the elements of security contained in certain chapters and articles of the Security Manual.

REPAIR DEPARTMENT ORGANIZATION

A ship's organization and regulation manual gives the ship's administrative organization; and it contains the administrative and operational bills, routine work details, and other details of duty to be performed by or assigned to the ship's divisions.

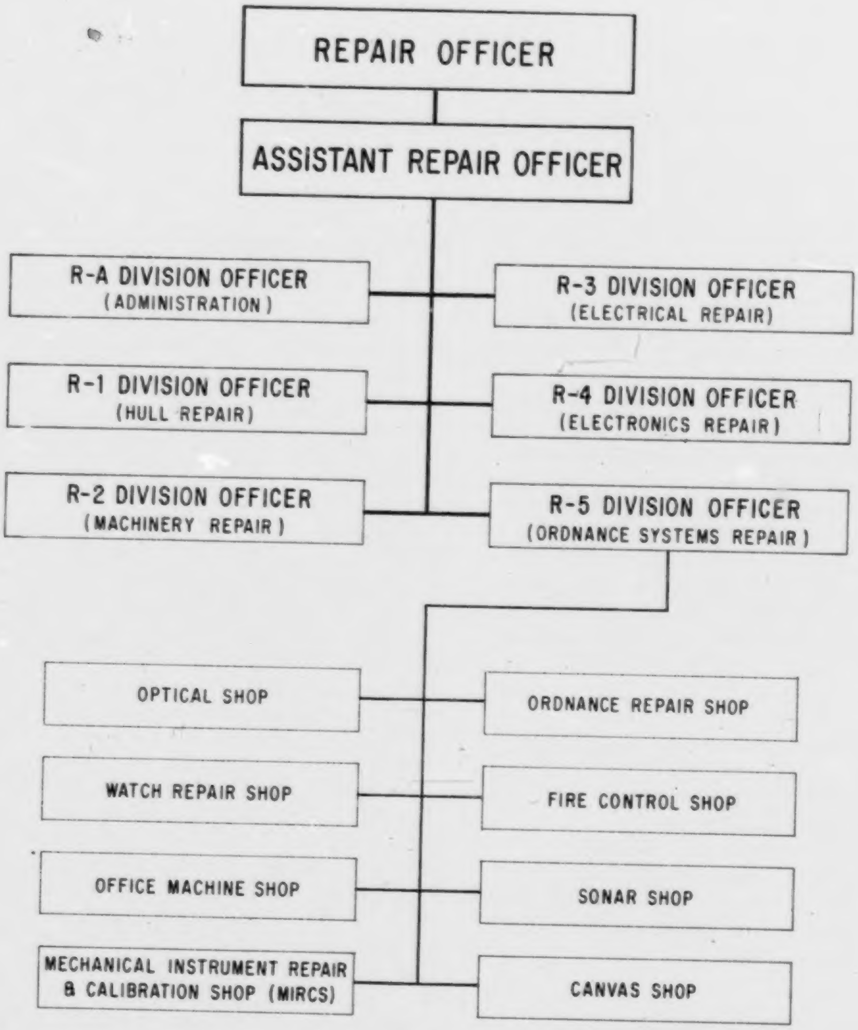
A department in a ship's organization is a segment of the organization; a division is a component of a department. A department is created for the sole purpose of carrying out specific responsibilities, such as engineering; a division is responsible for the execution of a definite portion of a department's mission. For the sake of better administration, a division is further divided into sections with specific functions. The size of a division varies from one or two members to over one hundred members.

The primary function of the repair department is the repair and maintenance of ships (and equipment) assigned by higher authority. A secondary mission of the repair department is the repair of the ship's own machinery and equipment.

Study illustration 2-1, which gives the administrative organization of the repair department in the USS Sierra (AD-18). The assistant repair officer is the division officer of the R-A division and has Yeomen assigned to help him administer the office—correspondence, records, reports, publications, instruction books, files, supplies, organization chart, maintenance of office space, and routing of work requests. All other division officers in the department are responsible for the functions listed below their division designation on figure 2-1. Observe that your division (Ordnance Systems Repair) on this ship contains five work centers and three instrument work centers. On other repair ships and tenders the instrument work centers may be in R-4 division or R-2 division. The administrative organization of the repair department on this ship is typical for repair ships and tenders, but it is not standard on all of them.

R-5 division is responsible for ordnance systems repair, and is generally comprised of eight work centers: optical, fire control, ordnance, sonar, canvas, watch, office machine, and MIRCS. The fire control work center conducts, for example, tests of electrical fire control circuits for continuity, grounds, short circuits; it also repairs, adjusts, and calibrates fire control radars.

The sonar work center repairs, tests, and calibrates all types of sonars, fire control systems, and fathometers used in naval ships; provides calibrated hydrophones to tended ships


REPAIR OFFICER
ASSISTANT REPAIR OFFICER
R-A DIVISION OFFICER (ADMINISTRATION)
R-3 DIVISION OFFICER (ELECTRICAL REPAIR)
R-1 DIVISION OFFICER (HULL REPAIR)
R-4 DIVISION OFFICER (ELECTRONICS REPAIR)
R-2 DIVISION OFFICER (MACHINERY REPAIR)
R-5 DIVISION OFFICER (ORDNANCE SYSTEMS REPAIR)
OPTICAL SHOP
ORDNANCE REPAIR SHOP
WATCH REPAIR SHOP
FIRE CONTROL SHOP
OFFICE MACHINE SHOP
SONAR SHOP
MECHANICAL INSTRUMENT REPAIR & CALIBRATION SHOP (MIRCS)
CANVAS SHOP

63.10-AD

Figure 2-1.—Administrative organization of the repair department in the USS Sierra (AD-18).

for calibrating their own units; provides tended ship's personnel technical assistance for repairs to sonar equipment; and accomplishes field changes and work related to underwater sound equipment.

The optical work center repairs, calibrates, and/or collimates binoculars (7 x 50 hand-held and 20 x 120 mounted), ship's telescopes, and gunsight telescopes; repairs parallel motion protractors, magnetic compasses, and other navigational instruments.

The canvas work center fabricates miscellaneous canvas covers, awnings, and boat cloths and also upholsters furniture.

The watch shop cleans, repairs, and adjusts for accuracy Navy clocks and watches, including battery-powered time pieces.

The office machine repair shop is responsible for cleaning, repairing, and adjusting standard and electric typewriters, adding machines, calculators, stencil process machines, and fluid, spirit, and direct process duplicators.

The mechanical instrument repair and calibration shops (MIRCS) work center repairs and calibrates pressure gages, pressure gage test and calibrating equipment, manometers, draft gages, barometers, tank level indicators, thermometers, revolution counters, tachometers, torque wrenches, and fluid meters. Fluid or flow meters are calibrated on only ARs having flow test stands.

REPAIR OFFICER

As the administrative head of the repair department, the repair officer is responsible to the commanding officer for the accomplishment of repairs and alterations to ships made available for such work by competent authority, and for such other duties as may be assigned. Specifically, he is responsible for:

1. Preparing estimates of funds required for the operation of his department.
2. Planning and scheduling work for his department.
3. Inspecting work in progress to ensure its timely and satisfactory completion.
4. Establishing and operating an adequate job order system.
5. Maintaining a record of charges for materials used in effecting repairs.
6. Performance of duty by assigned assistants.

ASSISTANT REPAIR OFFICER

Responsibilities of assistant department heads include: (1) supervision and training of assigned personnel; (2) care and use of equipage and stores charged to them; (3) unkeep and cleanliness of spaces; (4) maintenance of pertinent records; (5) preparation of required reports; and (6) such other duties as may be assigned.

In addition to the duties just listed, an assistant repair officer is also responsible for:

1. Administration of the repair department.
2. Reviewing of repair requests from assigned ships and assigning the requests to appropriate shops for necessary action—accomplishment of the work.
3. Administration of the R-A division, including the preparation of department correspondence.
4. Assignment of mess cooks, and management of assigned compartment (s).
5. Follow-up on work assigned to shops, to ensure timely and satisfactory completion.
6. Supervision of the preparation and final approval of a repair department watch list.
7. Inspection of shops for work procedures, work hazards, and cleanliness.
8. Handling of special requests from department personnel.
9. Review of division organization charts for balance of rated and non-rated men in each duty section.
10. Review (monthly) of division training records.
11. Performance of the duties of the repair officer during his absence.

SHIP SUPERINTENDENTS

The repair officer must assign a ship superintendent to a group of ships tended alongside, and also to ships of which your repair ship is MOTHER TENDER. This superintendent is a liaison officer between your ship and tended ships, and he assists the repair officer in maintaining daily progress of work in shops. All ship superintendents are assigned to the R-A division.

A ship superintendent is also responsible to the repair officer for the following:

1. Assigning shop responsibility and job order numbers to work requests.
2. Preparing progress sheets for job orders and maintaining files of all work requests received.
3. Routing of work requests to division officers 10 to 12 days prior to the commencement of an availability, when possible.
4. Collecting for review by the repair officer prior to the arrival conference ALL work requests on which division officers have made comments.
5. Noting changes in work requests agreed on at the arrival conference and correcting repair division officers' copies.
6. Visiting each repair shop daily and consulting with shop supervisors and division officers about their work, and recording on the progress sheet for each job order the percentage of completion.
7. Visiting each tended ship daily and advising the ship's liaison officer (normally the engineer officer) about the progress being made on each job and notifying him when to pick up

the completed work. (He must also check work requests of ships NOT alongside and notify them when to pick up completed work.)

8. Advising the repair officer immediately when a tended ship has a complaint of unsatisfactory or incomplete work, and informing him when a tended ship's personnel fail to cooperate with the repair ship's personnel.

9. Advising the repair officer immediately when urgent jobs are not progressing satisfactorily in shops, or when jobs are delayed because of lack of material.

10. Finding out when ships are scheduled for assignment to his repair ship, and advising his repair officer two weeks prior to the availability date.

11. Keeping work requests complete — manhour data, name and rate of shop supervisor, person who performed the work, name and rank/rate of tended ship's inspector who inspected and accepted the work, and the date. NOTE: Initials in lieu of a name are unacceptable.

12. Discussing with the repair officer all problems connected with the repair work, and doing such other work as requested.

DUTY REPAIR OFFICER

A duty repair officer is a repair department officer assigned to serve in this capacity from 0800 to 0800 the following day. His responsibilities include the following:

1. Assuming the duties of the repair officer and assistant repair officer in their absence.
2. Inspecting frequently, after normal working hours, repair department working and living spaces.
3. In port, making 2000 reports to the command duty officer relative to the security of the department, the men and boats away from the ship on repair work, and the approximate time the shops will secure.
4. Reporting to the repair officer, or the assistant repair officer, prior to 1600 on work days for briefing of repairs to be accomplished after normal working hours.
5. Approving, expediting, and supervising emergency repair work after normal working hours.
6. Calling the repair officer when necessary, and performing all assigned duties.

DUTY REPAIR CHIEF PETTY OFFICER

Each day one chief petty officer from the repair department is assigned the duties of duty repair chief. His tour of duty commences at 0800 and ends at 0800 the following day. He must:

1. Assist the duty repair officer in the performance of his duties.
2. Muster the watch section immediately after quarters, and determine at this time whether men appointed to watches were instructed concerning their duties. NOTE: Watches and duties involved are listed in the Repair Department Organization and Regulations Manual. He must then have the men initial alongside their names on the watch sheet to indicate that they understand their duties and know the time and place of their watch assignments.
3. Inspect berthing spaces and repair department shop spaces on an AS NECESSARY basis (and after normal working hours) for cleanliness, safety and fire hazards, locked tool cabinets and storerooms; and he must take prompt action whenever necessary by calling the division duty petty officers to have deficiencies corrected.
4. Make inspections of repair department living quarters at reveille and see that duty division petty officers hold reveille promptly.
5. Report to the duty repair officer prior to taps and accompany him in making his inspection of repair department spaces. Deficiencies must be corrected on the spot. Unsatisfactory conditions must be reported by memorandum to the repair officer.

DUTY DIVISION PETTY OFFICER

Each day one LEADING petty officer from each division's duty section is assigned as duty division petty officer. On normal work days, his tour lasts from the end of the normal work day until 0800 the following day. On Saturdays, Sundays, and holidays, his tour of duty lasts from 0800 to 0800. His duties include:

1. Inspecting division shop spaces at the end of working hours for security, and making a report to the duty repair officer at 1600 and 1900.
2. Informing the duty repair officer concerning the progress of urgent repair work.
3. Seeing that only authorized personnel use machinery, and that workers are complying with existing orders, instructions, and safety precautions.
4. Making certain that no fire hazard or accident hazards exist in berthing and shop spaces.

5. Ensuring that tools found adrift are returned to toolrooms and that the toolrooms are locked.

6. In the absence of the shop supervisor, taking charge of the repair work of his division after normal working hours.

DUTY POLICE PETTY OFFICER

In compliance with ship's instructions, generally, each division officer designates a senior petty officer (normally a PO1) as division police petty officer and others as duty section division police petty officers. When underway, the duties of the senior division police petty officer are continuous; when in port, his duties are from 0800 to 0800. On week days, the duties of the duty section division police petty officer commence at the end of working hours and end at 0800 the following morning. On Saturdays, Sundays, and holidays, his duties commence at 0800 and end at 0800 the following day.

The division police petty officer acts as Master-at-Arms for the division, and reports directly to the CMAA. The duty section division police petty officer acts as Master-at-Arms for the division during hours of liberty, and reports directly to the Duty Master-at-Arms. The Chief Master-at-Arms issues badges to the division police petty officers, who must wear them when on duty. The division police petty officer must enforce the ship's orders, instructions, Navy Regulations, and effective orders within his own division. The division police petty officers must see that men of their division turn into their bunks at taps and turn out at reveille. Each division police petty officer must inspect his berthing spaces, heads, and washrooms for compliance with cleanliness regulations.

REPAIR DIVISION SHOP SUPERVISOR

The leading petty officer in each shop is generally the shop supervisor and shop safety engineer. His duties are what yours will be when you are the leading petty officer in an instrument shop, and they include:

1. Planning, scheduling, and maintaining (under the division officer) a progress chart of the shop work load.
2. Expediting the completion of work requested, and ensuring by frequent inspections that repairs are accomplished in a satisfactory manner.
3. Advising your division officer relative to production lags.
4. Maintaining order and discipline in the shop.
5. Keeping shop equipment clean and in excellent condition, and shop spaces free from fire and accident hazards.
6. Posting operating and safety instructions on all portable and stationary shop machinery and tools.
7. Ensuring that shop personnel are proficient in the operation of shop equipment and tools before they are assigned (authorized) to use them.
8. Enforcing safe work habits, taking every precaution to prevent injury to personnel and damage to shop equipment because of carelessness and/or improper operation; and if necessary, removing a machine operator from a job.
9. Ensuring that each machine operator takes proper care of his machine and keeps it clean.
10. Signing custody receipts for tools and equipment issued to your shop, as required; and keeping records of tools issued from your toolroom and taking inventories as directed.
11. Making certain that tool room custodians keep tools in good condition and that they requisition replacements for worn or broken tools. NOTE: In order to maintain proper accountability for tools, keep a check-out and a check-in sheet on tool issues and receipts.
12. Making recommendations on special requests submitted by subordinates in the shop. (Explain reasons for disapproval to the division officer.)
13. Having the person in charge of a job sign his name in the block provided on the work request (when he completes the job). NOTE: Sign your own name also to indicate that you inspected the work and found it satisfactory.
14. Informing the division duty repair petty officer at the end of the working day of urgent work which must be completed during the night.
15. Inspecting shop spaces and making 1600 and 1900 securing reports to the division officer underway. (This report must contain the following: security of shop spaces, men working on special jobs, and the time when the men are expected to secure from work.)

GROUP SUPERVISOR

As an Instrumentman 1 or Chief Instrumentman, you will have many responsibilities added to those which you had at the next lower level.

The higher your pay grade, the more likely it will be that your main duties will consist of supervising rather than doing.

In earlier paragraphs you learned the department and division organization and the part you will play in interpreting and executing the established policies and procedures. How will you actually accomplish the apparently formidable task of supervising your personnel to accomplish the mission of your instrument shop? The following paragraphs will discuss fundamentals of job supervision whose application will enable you to plan, control, delegate work, and generally become a more effective supervisor.

SUPERVISION

The term supervision may be defined in a number of ways. As used in this chapter, it means overseeing, directing, and inspecting the work of others.

Supervision, then, means working with people. A good supervisor knows how to get a better job done, safely, accurately, and swiftly by getting the best out of his men. This is the basic difference between a supervisor who is merely technically competent and one who knows how to get maximum production safely. It is extremely important, of course, for a supervisor to be technically competent in his specialty. Competence alone, however, will rarely get the job done when a person has to direct the work of others. As well as knowing and understanding the job to be done, a good supervisor must understand the capabilities of his men and must know the techniques of good supervision.

Know Your Job

You may be in charge of a crew assigned to carry out any one of a number of jobs. To carry out the job properly, you must know exactly what is to be accomplished, deadlines for the job or portions of it, and the relationship of this job with other projects. You will need to plan your part of the job with respect to materials and scheduling. Unless you understand lines of authority, materials and equipment required, limitations of the equipment, and the capabilities of your crew, you are likely to have trouble in meeting your responsibilities.

Know Your Crew

It is not likely that you can do a good job unless you thoroughly understand the job to be done. Knowing your crew may be as important as knowing the job. If a new IM2 is assigned to your crew, you can be certain that he has been checked out in the practical factors for his rate and that he has passed the service-wide exam. Without investigation, however, you could not tell whether he is an expert in the use of test equipment or whether this is one of his weak points. Similarly, you could not tell whether he is almost ready for promotion to IM1 or whether he has just made his rate. His experience and capabilities will have a very important effect upon the type of assignment that he can handle best. Without checking, you cannot tell whether a new man is one to whom you can give very brief instructions and expect to find the job done, or whether you must keep a constant check on him. His traits may mean that you can assign him to a project where he can work under minimum supervision; or they may indicate that you should put him in a job where you can keep an eye on him and place a man who can work under less supervision on the project.

From the foregoing, it is obvious that a good supervisor needs to know the strong points and weak points of each crew member. You need to know your crew in order to make intelligent decisions about assignments, needed training, and recommendations for advancement in rating, among other things.

When you learn that a new man is being assigned to your crew, learn what you can about him; ask to see his record. Talk to him when he reports; find out what he has done and likes to do.

Show your interest in him; and let him know how important he is as a member of your team. If you use this approach, training will be much easier; and the work from your shop will be better and more productive. Best results in handling personnel can usually be accomplished through calmness and mutual understanding. Always be fair and honest with each person.

Finally, observe him closely in various work situations; you will soon learn what type of person he is and his capabilities.

Delegating

Delegation means giving one person the authority to act for another. It means that we give another man the right to make certain decisions for us. This is exactly why many of us have difficulty when we delegate. We are afraid of the risks involved. Some of these include the possibilities of costly mistakes, loss of control of an activity, and the all-inclusive excuse that we have no one to whom we can delegate the authority.

One of the most common failings of a new supervisor is failure to delegate. It is natural to want to carry out the details of a job yourself, particularly when you know that you can do the job better than any of your men. Trying to do too much, however, is one of the quickest ways to get bogged down in details and to slow down a large operation. You will often be responsible for several jobs or several parts of a job some distance apart. Obviously, you cannot be in two places at the same time. If someone may be needed to make quick decisions during your absence, designate a man who is capable of making these decisions. This man should be capable of supervising the work in your absence, seeing that needed materials and supplies are on hand, and, in general, making the work go forward. Naturally, you should select a man for this job who can work without close supervision. Make him understand what you expect of him, and be specific concerning the limits of his authority. For example, you should make clear to him that the specifications for the job must be followed unless they are changed by higher authority.

Delegation difficulties may be minimized by using some time-tested techniques.

- Assign as many of those tasks as you safely can.
- Expect mistakes on the part of your subordinates.
- Make sure that adequate authority goes with the responsibility given.
- Let others know the person who is in charge and to whom they will be responsible.
- Control the delegation—require the men to report their progress and any troubles or abnormal conditions.

Remember, no one man can do everything and the faster you learn that you as a supervisor are required to organize, direct, plan, and perform many other managerial functions, the sooner you will appreciate how the potent technique of delegation will enable you to perform these other functions more effectively.

Job Inspections

Periodic inspections are one important method of ensuring proper quality of work done under your supervision. Let your men know that their work is likely to be inspected. When you make an inspection let the men concerned know how well or how poorly they did the job. A man's work is not likely to improve if he is not told specifically wherein his work needs improvement; and a man who has done an excellent job will be motivated to continue this level of work if you let him know that good work is noted and appreciated.

Communication

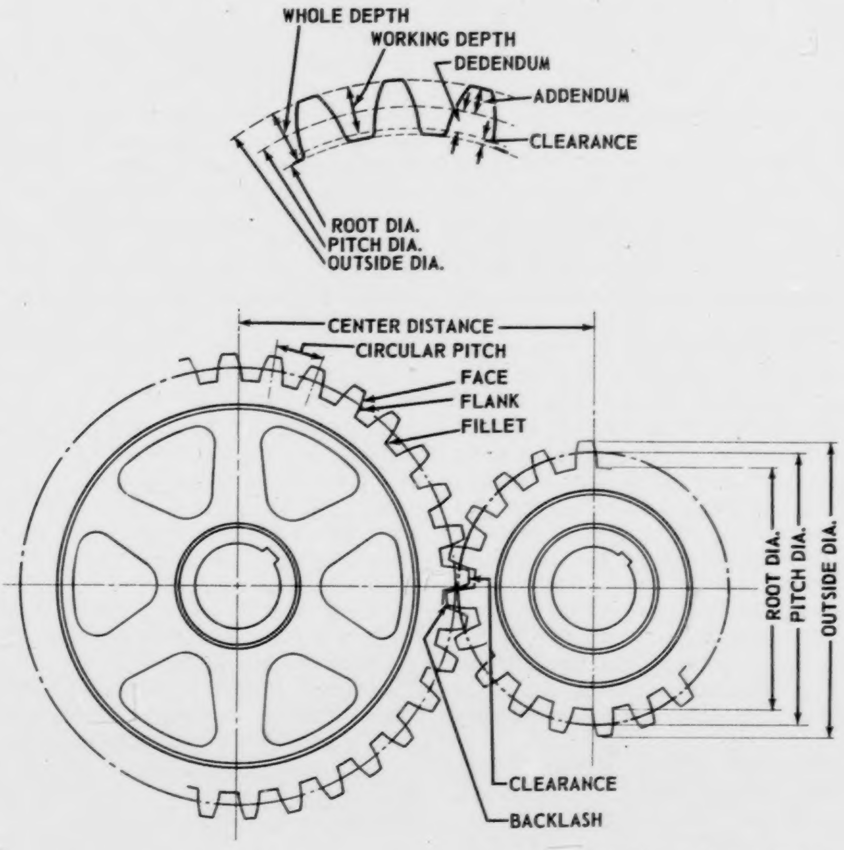
Passing the word is an important part of supervision. The commanding officer, executive officer, department head, division officer, and other higher authorities frequently issue orders or directives which you should pass on to your men. You should be familiar with all instructions and notices that affect your work and the work of your men and make certain that they have this information.

Orders and directives from higher authority may pertain to a particular job, recreation, liberty, military requirements, or safety. If the information is the type that you can pass orally, you should consider the best time to pass the word on. Morning quarters and special musters are often suitable times.

You will need to put certain types of information into writing in the form of a written directive. Considerable personnel turnover exists in most units, and it takes a new man several weeks or months to learn about all policies. His task is even harder if there are no written directives to which he can refer. Safety requirements, local policies with respect to the use of Government material, tools, and equipment, and local shop rules are examples of information which should normally be in written form.

A simple drawing is another form of communication (fig. 2-2). When appropriate symbols, dimensions and materials are marked clearly on the sketch, its easy to follow. For further information regarding the reading of drawings and technical sketchs, see Blueprint Reading and Sketching, NavPers 10077.

Remember—communication is the process of conveying information and understanding to others. Never minimize the importance of good


WHOLE DEPTH
WORKING DEPTH
DEDENDUM
ADDENDUM
CLEARANCE
ROOT DIA.
PITCH DIA.
OUTSIDE DIA.
CENTER DISTANCE
CIRCULAR PITCH
FACE
FLANK
FILLET
ROOT DIA.
PITCH DIA.
OUTSIDE DIA.
CLEARANCE
BACKLASH

Courtesy of American Foundrymen's Society

23.119X

Figure 2-2.—Sketch of gear.

communication. It leads to better human relations and higher morale. Money, time, and lives can be saved if communications are accurate and fast. Obviously, no military organization can be truly effectively without good communication.

Bulletin boards are a convenient method for passing along information the men need. Keep the boards clear of extraneous information. One Chief was very successful in assuring that the men would read the bulletin board. He put little cartoons on it.

One obvious method of attracting attention toward the bulletin boards is to place the duty section lists there. Preparing the duty section lists and posting them on the bulletin board as far in advance as possible is a wonderful morale booster. It enables the men to make their plans well in advance and at the same time helps you since you know the names of the men in the duty sections, and can help anticipate your own manpower requirements more readily.

Keep bulletin boards CURRENT — not cluttered up. It is a good idea to make up a list showing the duties of each man assigned to the instrument shop. Such a list would show specifically the duties and responsibilities of each man and his assigned hours of work. Sometimes it will be necessary to work in shifts; advance notice to your men will enable them to plan their free time.

Communications can flow downward — to inform, instruct, direct, etc. Good communication will provide for an upward flow of information as well, in reports, recommendations, suggestions, and a permissive outlook on questions. Finally, a horizontal flow of information useful in coordination, maintaining good relations with other rates, etc., will be useful. Use all three flows. Your major responsibility with respect to communication is to ensure that everyone for whom and to whom you are responsible gets "the word" completely and accurately.

MORALE

Morale in the military may be defined as the mental state of attitude, confidence, or spirit which envelops men as they perform their duties. Good morale works wonders. One World War II veteran said, "Morale is when your hands and feet keep working when your head says it can't be done."

The new man coming into the Navy acquires and recognizes the necessity for discipline even though it sometimes causes him personal inconvenience. He also recognizes the need for fair play and reasonable requirements in the performance of duty. You will be better able to achieve a high standard of morale if you (1) develop satisfaction in a work program, (2) establish mutual confidence between yourself and your men, and (3) express and explain the conviction that by pulling together, you are striving for something more than yourselves. Remember,

HOWEVER ADVERSE THE GENERAL SITUATION, MEN WILL STICK TO THE ONE MAN WHO KNOWS WHAT HE WANTS THEM TO DO AND WELCOMES THEM TO A FULL SHARE IN THE ENTERPRISE.

Your diligence in the care of the men, impartial administration of all organizational affairs, military bearing in oneself, and ability to transfer all military information to your men, will build up and keep high the morale of your men.

RECORDS AND REPORTS

As you advance in rating to IM1 or IMC you will be required to assume more responsibility for the paperwork which is so necessary in a well organized work center. In fact, to avoid bogging down completely in the mass of details, you will probably delegate some of these duties to an assistant in the work center. Keeping all your records up to date will enable you to keep a close check on each job, each workman, and each piece of equipment under your supervision.

Introduction of the 3-M system aboard all tenders has eliminated the requirement for many of the records and reports used in the past. Feedback information is supplied to each division officer and work center supervisor on work request progress by the various reports generated by the 3-M system. For example, the work center supervisor's report includes, for each work request, such information as the completion status, man-hours expended and remaining, required completion date, and priority. The key to using the 3-M system to your benefit is to avoid duplication. Do not maintain records when the information is readily available elsewhere. At the same time, you will need to maintain records of information not readily available elsewhere, such as a shop equipment log, record of commonly used Federal Stock Numbers (FSN), and any other record you feel is required. A casualty inspection form is nonstandardized form for which you are also responsible. An example is shown in figure 2-3. Proper use of these forms will ensure that important steps are not overlooked. For example, suppose a man is called away from his job and returns to complete it, the form should remind him of tasks he has yet to do.

Standard forms are available for records and reports. Further information on records and reports may be found in NavShips Technical Manual, chapter 9004(6).

3-M UTILIZATION AND DOCUMENTATION

The Navy, as well as the other armed services, is required to maintain all weapons systems in the maximum possible degree of combat readiness. Previous systems for controlling and accomplishing required maintenance could not keep pace with the growing complexity of shipboard maintenance, increased tempo of fleet operations and constant decline in available resources. The Maintenance and Material Management (3-M) System was implemented in 1964 in an attempt to solve these problems. The 3-M system was designed to function as an integrated system which would improve the management of maintenance, and provide for the collection and dissemination of maintenance related information.

The 3-M system is not envisioned as a cure for all equipment problems and attendant maintenance resource demands, nor does it eliminate the urgent need for good leadership and supervision based on experience and reasoned judgement. The system will, however, produce a

INSPECTION SHEET

1. Function of winding ____________________
2. Clearance and fit of hands ____________________
3. Cleanliness, rust, fingerprints, etc. ____________________
4. Motion dial up ____________________
5. Motion dial down ____________________
6. Motion 12 up ____________________
7. Freedom of train ____________________
8. Condition of mainspring ____________________
9. Condition of balance assembly ____________________
10. Condition of Lock ____________________
11. Condition of Draw ____________________
12. Condition of Drop ____________________
13. Jewel pin shake ____________________
14. Guard pin shake ____________________
15. Jewels and holes ____________________
16. Side shakes and end shakes ____________________
17. Truth and poise, Bal. whl. ____________________
18. Condition of hairspring ____________________
19. Condition of all pivots ____________________
20. Condition of regulator pins ____________________
21. Review, general condition ____________________

Instrumentman ____________________ Date received ____________________
Movement name and no. ____________________ Date completed ____________________

Figure 2-3.—Inspection sheet. 91.419

logical and efficient approach to the solution of maintenance problems, and a large reservoir of knowledge about maintenance.

The 3-M system is an integrated management system which, when fully implemented and properly used, provides for orderly scheduling and accomplishment of maintenance and for reporting and disseminating significant maintenance related information. It is composed of the Planned Maintenance Subsystem, Maintenance Data Collection Subsystem, Workload Planning and Control Subsystem, and Man-hour Accounting Subsystem; it forms the nucleus of a shipboard maintenance program which can contribute significantly toward achieving improved fleet readiness with reduced expenditure of resources.

PLANNED MAINTENANCE SUBSYSTEM

The Planned Maintenance Subsystem (PMS) pertains to the planning, scheduling and management of resources (men, material and time) to perform those actions which contribute to the uninterrupted functioning of equipment within its design characteristics. It defines uniform maintenance standards, and prescribes simplified procedures and management techniques for the accomplishment of maintenance.

The PMS has been developed to provide each ship, each department and each supervisor, with the tools to plan, schedule and control shipboard planned maintenance effectively.

MAINTENANCE DATA COLLECTION SUBSYSTEM

The Maintenance Data Collection Subsystem provides a means for maintenance personnel to record information pertaining to preventive or corrective maintenance actions. The system uses coded data elements for recording much of this information in order to standardize the data collected and to facilitate its processing and use. The failure and corrective action information recorded on the maintenance action documents, and the material usage information recorded on associated supply documents, is retrievable through this system for engineering analysis and maintenance history.

Routine maintenance action reporting is actually accomplished on a multipurpose maintenance data collection form which, occasionally, is augmented by additional information reported on a related supplemental data reporting form. This maintenance data collection form (fig. 2-4) is used in reporting the completion or deferral of a maintenance action, or to request needed assistance. The data elements which must be completed to report any one of these categories of maintenance information have been grouped together in separate, clearly labeled sections of the form, to simplify data recording and to facilitate automatic data processing.

A complete discussion of the PMS and MDCS may be found in the military requirements rate training manuals for PO 3 & 2 and PO 1 & C or in the 3-M manual.

MDCS success is dependent upon the accuracy, adequacy and timeliness of the information reported into the system. This, in turn, means that responsible activities can not effectively analyze fleet maintenance problems, develop improvements to fleet equipment, or produce usable fleet maintenance management products unless maintenance and repair personnel actively support and use the MDCS. It is a system in which potential benefits are directly related to the efforts applied. Present programs for improving maintainability and reliability of fleet equipment are dependent upon conscientious adherence to required reporting procedures. The following general guidelines will aid in ensuring complete, accurate and prompt MDCS document submission.

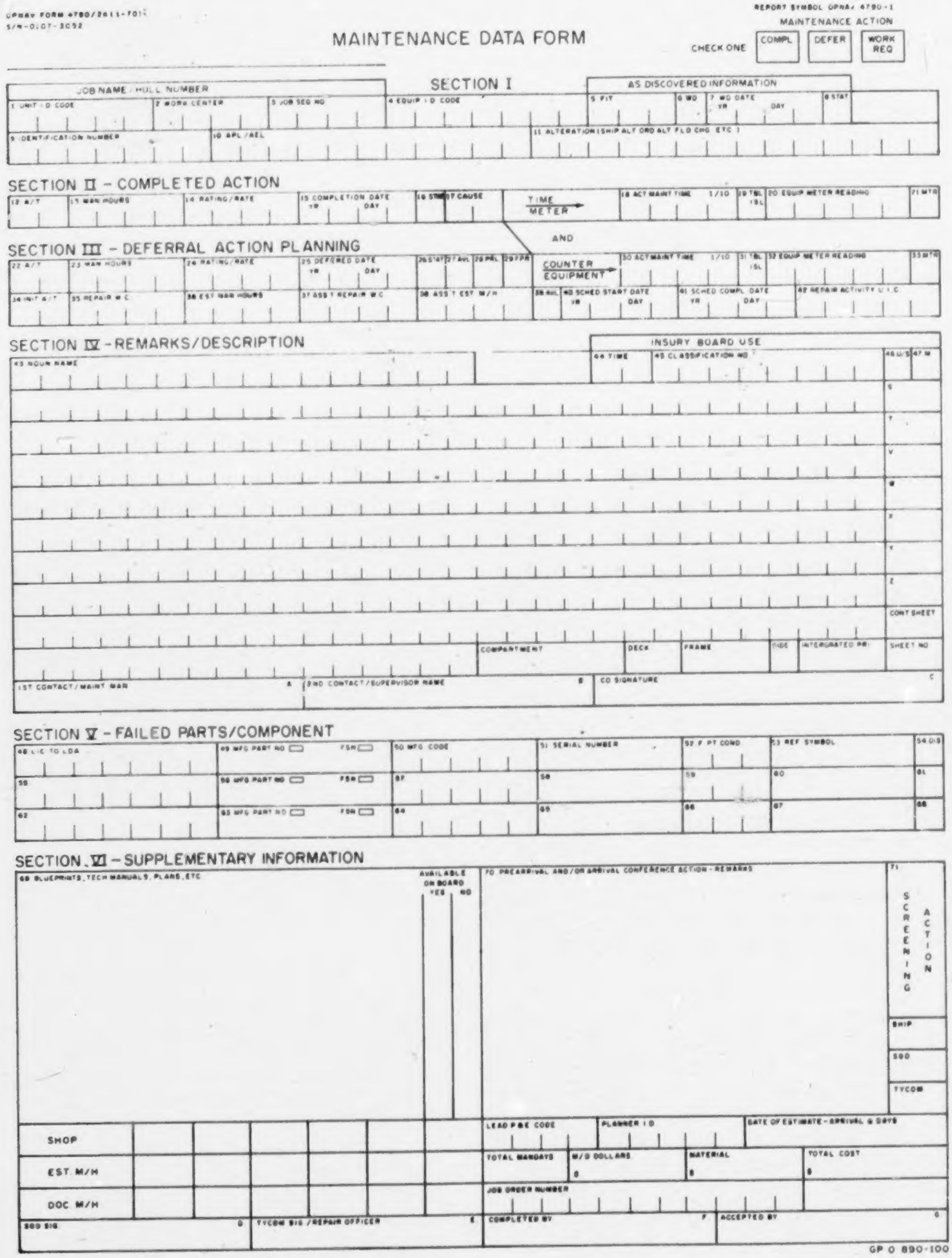
Work center supervisors will submit completed documents daily. To provide the information required by the MDCS, the OpNav 4790 series documents and the DD Form 1348 must be completed, as appropriate, for each reportable maintenance action. It is mandatory that all applicable blocks on the forms be filled in correctly, to avoid rejection during data processing and to ensure accurate information for maintenance history.

Past experience indicates that the guidelines presented in this chapter will be directly applicable and adequate, in most cases, but common sense and good judgement must be exercised in reporting any maintenance action, particularly those not specifically covered by these instructions and examples. The senior maintenance man actively engaged in the maintenance action is responsible for completing the required entries on the maintenance action form and submitting it to his supervisor for review, approval and forwarding.

THE WORKLOAD PLANNING AND CONTROL SUBSYSTEM

The Workload Planning and Control Subsystem (WLP&C) is a management system used in the repair and weapons repair departments of a tender/repair ship. The system provides for a systematic approach to the planning, scheduling, monitoring and reporting of all work accomplished.

The objective of the WLP&C subsystem is to give managers of intermediate level maintenance activities a method to effectively plan and control work accomplished. The system is divided into two phases. One is the planning and estimating of work to be accomplished, and the other is the reporting of work as it is being accomplished.



OPNAV FORM 4790/2K11-701
S/N-0107-3052

REPORT SYMBOL OPNAV 4790-1

MAINTENANCE DATA FORM

MAINTENANCE ACTION
CHECK ONE ☐ COMPL ☐ DEFER ☐ WORK REQ

SECTION I

JOB NAME / HULL NUMBER
1 UNIT I D CODE
2 WORK CENTER
3 JOB SEQ NO
4 EQUIP I D CODE

AS DISCOVERED INFORMATION
5 FIT
6 WD
7 WD DATE YR DAY
8 STAT

9 IDENTIFICATION NUMBER
10 APL / AEL
11 ALTERATION (SHIP ALT ORD ALT FLD CHG ETC)

SECTION II - COMPLETED ACTION

12 A/T
13 MAN HOURS
14 RATING/RATE
15 COMPLETION DATE YR DAY
16 ST
17 CAUSE
TIME METER
18 ACT MAINT TIME 1/10
19 TBL ISL
20 EQUIP METER READING
21 MTR

AND

SECTION III - DEFERRAL ACTION PLANNING

22 A/T
23 MAN HOURS
24 RATING/RATE
25 DEFERRED DATE YR DAY
26 STAT
27 AVL
28 PRL
29 PR
COUNTER EQUIPMENT
30 ACT MAINT TIME 1/10
31 TBL ISL
32 EQUIP METER READING
33 MTR

34 INIT A/T
35 REPAIR W C
36 EST MAN HOURS
37 ASS T REPAIR W C
38 ASS T EST M/H
39 AVL
40 SCHED START DATE YR DAY
41 SCHED COMPL DATE YR DAY
42 REPAIR ACTIVITY U I C

SECTION IV - REMARKS/DESCRIPTION

INSURV BOARD USE
43 NOUN NAME
44 TIME
45 CLASSIFICATION NO
46 U/S
47 M

S
T
V
W
X
Y
Z
CONT SHEET

COMPARTMENT
DECK
FRAME
SIDE
INTEGRATED PRI
SHEET NO

1ST CONTACT/MAINT MAN A
2ND CONTACT/SUPERVISOR NAME B
CO SIGNATURE C

SECTION V - FAILED PARTS/COMPONENT

48 LIC TO LDA	49 MFG PART NO ☐ FSN ☐	50 MFG CODE	51 SERIAL NUMBER	52 F PT COND	53 REF SYMBOL	54 DIS
55	56 MFG PART NO ☐ FSN ☐	57	58	59	60	61
62	63 MFG PART NO ☐ FSN ☐	64	65	66	67	68

SECTION VI - SUPPLEMENTARY INFORMATION

69 BLUEPRINTS, TECH MANUALS, PLANS, ETC
AVAILABLE ON BOARD YES NO
70 PREARRIVAL AND/OR ARRIVAL CONFERENCE ACTION - REMARKS
71 SCREENING ACTION
SHIP
SOO
TYCOM

SHOP						
EST M/H						
DOC M/H						

LEAD P&E CODE
PLANNER I D
DATE OF ESTIMATE - ARRIVAL & DAYS
TOTAL MANDAYS
M/D DOLLARS $
MATERIAL $
TOTAL COST $
JOB ORDER NUMBER

SOO SIG D
TYCOM SIG / REPAIR OFFICER E
COMPLETED BY F
ACCEPTED BY G

GP O 890-100

17.81K

Figure 2-4. — Maintenance Data Form.

During the planning phase, work requests (OpNav Form 4790/2K) are received by the maintenance activity. These are screened and used to assign work centers to each work request and estimate the amount of work required. Initial planning action may be significantly changed by arrival conference trade-offs or priority designations.

The WLP&C subsystem is designed to operate within the department framework of the basic shipboard organization, and specifically the repair organization of a intermediate level maintenance activity.

The repair officer has primary responsibility for the effectiveness of the WLP&C subsystem within the repair department. The functions assigned to the repair officer of an intermediate maintenance activity are considered to be those functions now being performed by them or their representatives.

The 3-M coordinator serves as the liaison between the work centers, data services and other personnel within the repair department. The coordinator is responsible for:

Distribution of all workload planning and control products generated by data services, screening and controlling 3-M related documents prior to submission to data services, returning all erroneous documents to work centers or ships concerned, analyzing collected data, and devising reports for the presentation of 3-M information when required.

Upon receipt of all work request documents from the coordinator, data services keypunches the appropriate card type for each document. Sheets 1 and 2 of the work request, work supplement cards, failed parts/components cards and reports generated by the computer are returned to the coordinator for distribution and/or filing.

An original and two copies of a work request will be received by the repair department for each maintenance action desired. These will normally be delivered as a work package with appropriate screening approval for a scheduled availability period. It is extremely important that the work assigned to the work center, the start and completion date, and the estimate of man-hours be made as realistically as possible. Careful consideration should be given to the length of the availability, manpower available during the period, other work load commitments, and the availability of necessary tools, manuals, and other materials. The planning information entered on the work requests will be the basis of work center work load figures on various reports.

Repair Office Action

The initial action on a work request is performed by the coordinator and it is his responsibility to screen the work request for completeness, legibility, and validity of all entries. In addition, the coordinator will make the following entries, and forward all copies to the repair officer.

Block 39: Availability. Enter the code for the actual type availability under which the job will be accomplished.

Block 42: Repair Activity UIC. Enter the unit identification code of the repair activity.

Repair Officer

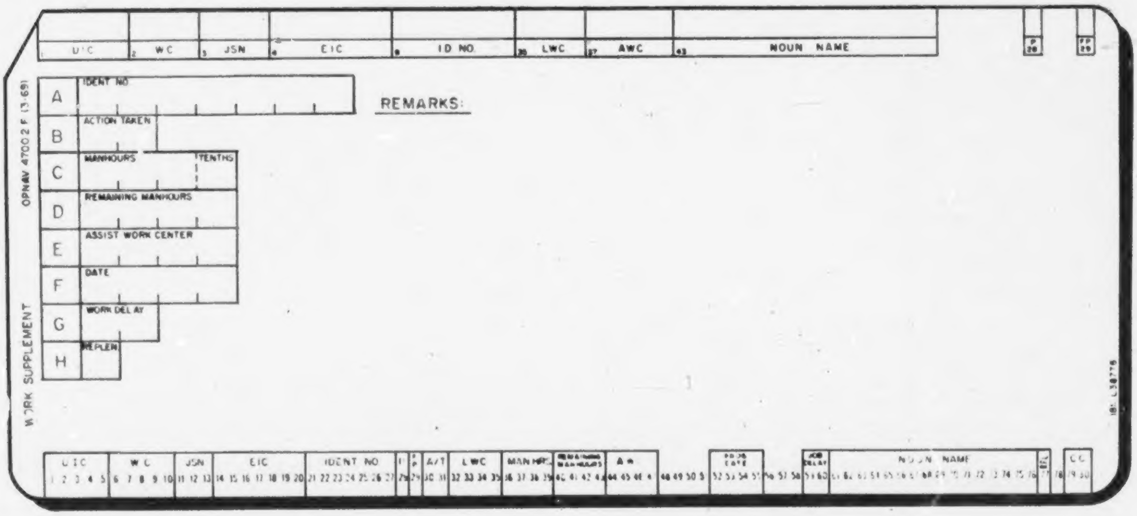
It is the responsibility of the repair officer to screen the work request and determine if there are problem areas and/or scheduling difficulties. After the initial review by the repair officer, the work request is returned to the coordinator. The coordinator removes sheet 3 and retains it as a record, forwarding sheets 1 and 2 to the appropriate division officer for job planning. The coordinator must provide each division officer with the expected date and duration of each scheduled availability.

Division Officer/Lead Work Center Actions

Upon receipt of sheets 1 and 2 of the work request the division officer, in conjunction with the lead work center (LWC) supervisor, assist work center (AWC) supervisors, and other involved personnel will plan the job for completion. To expedite processing, the LWC will obtain and document the planning information for the AWCs. The lead work center supervisor is responsible for documenting the following planning information. Enter the information on sheets 1 and 2 of the work request as follows.

Block 34: Initial Action Taken. Enter Acceptance Code W1.

Block 35: Repair Work Center. Enter the code which identifies the work center with primary responsibility for completion of the job.



UIC
WC
JSN
EIC
ID NO.
LWC
AWC
NOUN NAME

A IDENT NO.
B ACTION TAKEN
C MANHOURS TENTHS
D REMAINING MANHOURS
E ASSIST WORK CENTER
F DATE
G WORK DELAY
H REPLEN

REMARKS:

OPNAV 4700 2 F (3-69)
WORK SUPPLEMENT

UIC
WC
JSN
EIC
IDENT NO
A/T
LWC
MAN HRS
REMAINING MAN HOURS
AW
JOB DELAY
NOUN NAME
CC

17.81F

Figure 2-5.—OpNav Form 4790/2F Work Supplement Card (Front).

When the work center code has only three symbols such as 35A, 35B, etc, enter from left to right in block 35, leaving the fourth space blank.

Block 36: Estimated Man-hours. Enter the estimated man-hours (whole hours) required to complete the lead work center's portion of the job.

Block 37: Repair Assist Work Center. If required, enter the code of the work center or outside repair activity that will assist the LWC. During initial planning if more than one AWC is involved, enter each additional AWC code and the estimated man-hours for each in the blocks labelled "SHOP" and EST. M/H" provided at the bottom of the form.

Block 38: Assist Estimated Man-hours. Obtain and enter the estimated man-hours (whole hours) for the AWC reflected in block 37.

Block 40: Scheduled Start Date. Enter the Julian date the job is actually planned to be started.

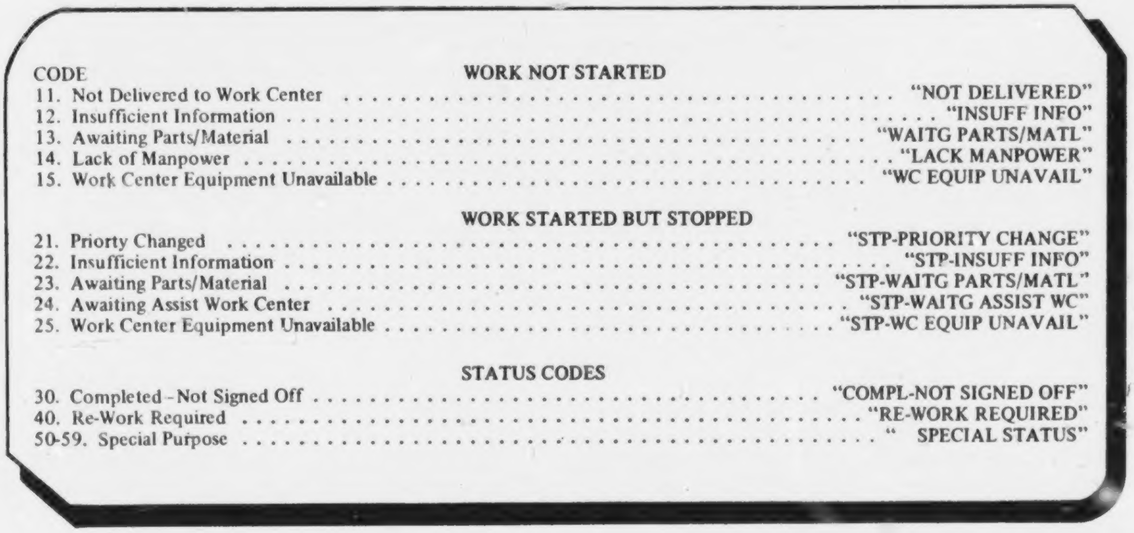
Block 41: Scheduled Completion Date. Enter the Julian date the job is actually planned to be completed. Sheet 2 will be forwarded to data services via the coordinator. Sheet 1 will remain on file in the LWC.

Procedures for Documenting Repair Activity Maintenance Action

The work center supervisor is responsible for the correct documentation of all maintenance actions accomplished within his work center. Preprinted/prepunched work supplement cards will be provided by data services. The Work Supplement Card (OpNav Form 4790/2F) will be used primarily to report daily job progress by repair work centers. The DOD Single Line Item Requisition Document (DD Form 1348) is the source document used to record material usage and cost information. Sheet 1 of the work request will be used by the LWC to close out the work request.

WORK SUPPLEMENT CARD OPNAV FORM 4790/2F.—Prepunched/Preprinted cards (fig. 2-5) will be supplied to the LWC and each AWC included in the initial planning phase of the work request. The cards will be used primarily by repair work centers to report daily progress (action taken, man-hours, date) on a work request. It may also be used to record remaining hours, report work delay/status and request additional prepunched/preprinted work supplement cards.

The LWC may use a 4790/2F card to request assistance. The AWC will use the same card to estimate their portion of the job and request



CODE		
	WORK NOT STARTED	
11.	Not Delivered to Work Center	"NOT DELIVERED"
12.	Insufficient Information	"INSUFF INFO"
13.	Awaiting Parts/Material	"WAITG PARTS/MATL"
14.	Lack of Manpower	"LACK MANPOWER"
15.	Work Center Equipment Unavailable	"WC EQUIP UNAVAIL"
	WORK STARTED BUT STOPPED	
21.	Priorty Changed	"STP-PRIORITY CHANGE"
22.	Insufficient Information	"STP-INSUFF INFO"
23.	Awaiting Parts/Material	"STP-WAITG PARTS/MATL"
24.	Awaiting Assist Work Center	"STP-WAITG ASSIST WC"
25.	Work Center Equipment Unavailable	"STP-WC EQUIP UNAVAIL"
	STATUS CODES	
30.	Completed - Not Signed Off	"COMPL-NOT SIGNED OFF"
40.	Re-Work Required	"RE-WORK REQUIRED"
50-59.	Special Purpose	" SPECIAL STATUS"

17.81F

Figure 2-6.—OpNav Form 4790/2F Work Supplement Card (Reverse) Work Delay and Status Codes.

prepunched/preprinted cards. Information from these cards is used for the workload planning and control reports. Handscribed (Blank) 4790/2F cards may be submitted whenever the preprinted/prepunched cards are not available by transcribing the appropriate information from the 4790/2K onto the blank card. Blocks 1, 2, 3, 4, and 35, must be transcribed. Blocks A through H of the card will be filled in as appropriate.

A 4790/2F card will be used to document all man-hours expended on each job in progress within the work center. The senior man actively engaged in the maintenance action is responsible for documenting daily progress.

Whenever the remaining hours as listed on WLP&C reports do not accurately reflect the scope of the job for this work center, this figure can be revised, either up or down, by simply entering the hours remaining on the job in block D. This can be done by submitting a 4790/2F, or may be included with daily progress information.

A 4790/2F card can be used to report work delays or work stoppage affecting satisfactory progress of a job. The lead work center and each assist work center may use the work delay/stoppages codes (block G) to reflect problems associated with the job in that work center. Work delay/stoppage codes are found on the reverse of the 4790/2F (fig. 2-6). There can be only one work delay/stoppage code effective at any one time for any specific work center. The latest delay code that is submitted will be reflected on WLP&C reports. The delay code 00 will be used to remove the delay status from that work center's WLP&C reports.

Replenishment of the prepunched/preprinted 4790-2F cards can be accomplished by submitting a card for that specific purpose or in conjunction with daily progress documentation by entering the number of cards desired (1-9) in block H.

When additional repair work centers are required to complete the requested work, the lead work center will provide the assist work center with two or more prepunched/preprinted work supplement cards. One is to establish the AWC job planning record, and the other is for reporting progress prior to data services providing the assist work center with prepunched/preprinted work supplement cards.

Completion of a work request can be reported using a 4790/2F and entering the code 30 in block G. Assist work centers may also report completion of their portion of a job by using code 30 (block G) on the 4790/2F. Sheet 1 of the 4790/2K must be completed (section

II) and submitted following the code 30 submission by a lead work center for the job to be closed out.

Occasionally jobs must be reopened after the lead work center or assist work center has reported completion (code 30 on 4790/2F). This can be accomplished by submitting another 4790/2F with the code 40 entered in block G. (Submission of a code 40 4790/2F card will remove the last action taken code from the data processing file. The job may be reestimated at this time by including an entry in the remaining hours block (D). If sheet 1 of the 4790/2K has been processed through data services, the entire job must be resubmitted (new 4790/2K).

Multiple unit work requests on items such as binoculars, printing, photographing, plaques, sound-powered phones, clocks, etc are permitted by using the words "various" or "miscell" in block 9 of the work request. Block 9 of the prepunched 4790/2F card will always be blank when associated with this type work request. These multiple items will always be documented as a single maintenance action unless rejection of individually serialized items is involved. When individually serialized items are rejected, the rejection action taken code must be on a one-for-one basis for each item. For nonserialized items or whenever rejection is not involved, the action taken code that best describes the overall effort will be recorded.

Procedures for Use of the Work Supplement Card by Lead Work Center

Block A: IDENTIFICATION NO. Enter only when a serialized item is REJECTED and block 9 is blank.

Block B: ACTION TAKEN. Enter the code which best describes the action taken when the requested work is completed.

Enter 00 if the job is in progress.

Enter the appropriate REJECTION code when block A contains an entry.

Block C: MAN-HOURS. Enter the direct labor man-hours (to the nearest tenth) expended against the reported action or 0000 may be entered.

Block D: REMAINING MAN-HOURS. May be blank or whole hours may be entered when the current WLP&C reports inaccurately reflect the man-hours required to complete the requested work.

Block E: ASSIST WORK CENTER. May be blank or the lead work center will enter the assist work center code when requesting assistance.

Block F: DATE. Enter the Julian date for which the card is being submitted.

Block G: WORK DELAY. (for work center supervisor use only) May be blank or if the work has been stopped, enter the code from the back of the card which best describes the stoppage.

If the work is completed, but not signed off, enter status code 30.

After previously submitting status code 30, if the job is not accepted by the requesting activity and must be progressed further or reworked, enter status code 40.

Code 00 will be entered to remove any previously submitted delay/status code.

Block H: REPLENISH. May be blank or when additional prepunched/preprinted work supplement cards are required enter the desired number of cards in this block (9 cards maximum).

A replenishment request and a maintenance action may be documented on the same card.

Assist Work Center (AWC) Procedures (Subsequent to Initial Work Request Planning)

When requested for assistance on a work supplement card the AWC will receive a minimum of two prepunched/preprinted work supplement cards from the lead work center, ensuring that block E on all cards contains the proper AWC code. One card (planning card) will be used to establish a job planning record for the AWC and will be used for planning information only. The other card(s) will be used by the AWC to report job progress while awaiting prepunched/preprinted work supplement cards. The AWC will complete the entries on the planning card.

PROCEDURES FOR USE OF THE WORK SUPPLEMENT CARD BY AWC. — The procedures for blocks B, C, F, and H are the same for the LWC and AWC.

Block A: IDENTIFICATION NO. Must be blank.

Block D: REMAINING MAN-HOURS. May be blank or whole hours may be entered when the current WLP&C reports inaccurately reflect the man-hours required to complete the requested work.

Will be entered as the initial estimate when this work center was not included on the initial planning of the work request.

Block E: ASSIST WORK CENTER. May be blank or must be blank if the assist work center code appears in block 37.

Must be entered if block 37 is blank.

Block G: WORK DELAY. (for assist work center supervisor use only) May be blank or if job or portion of the job has been stopped enter the code from the back of the card which best describes the stoppage.

Enter status code 30 when assistance is completed.

Procedures for Closing Out a Work Request

A work request may be signaled (status code 30) as completed when a properly coded supplement card has been processed. However, it will not be closed out until sheet 1 of the work request has been documented and processed through data services.

The lead work center must complete documentation on sheet 1 as follows:

Check the "COMPL" block in the upper right corner of the form.

Block 12: ACTION TAKEN. Enter the action taken code which best describes the completed maintenance action. Enter 00 if an action taken code and job status code 30 were previously submitted on a 4790/2F card.

Block 13: MAN-HOURS. Enter the number of man-hours (to the nearest tenth) expended on the requested maintenance since the last progress card was submitted. Enter 0000 in block 13 if all man-hours have been submitted on 4790/2F cards.

Block 14: RATING/RATE. Enter the rating/rate of the senior man actively engaged in the maintenance action.

EXAMPLES FOR BLOCK 14:

RANK/RATE/GRADE/CODE	ENTRY
ALL OFFICERS/MIDSHIPMEN	O F F
IM1	IM 1
IM2	IM 2
IMSN	I M S N
SN	S N
GS9	G S 9
CIVILIAN	C I V
WAGE BOARD EMPLOYEE (LEVEL)	W B 3
MARINE (PAYGRADE)	M A R 6

Block 15: COMPLETION DATE. Enter the Julian date the maintenance action is completed. (acceptance by requesting activity)

Block 16: STATUS. Enter the status code 5 in this block.

Block 17: CAUSE. Enter the appropriate code which best describe the cause of the failure.

Block F: COMPLETED BY. The senior maintenance man actively engaged in the action will sign this block indicating the job is complete.

Block G: ACCEPTED BY. The repair work center will have the contact person from the requesting ship sign this block to indicate the job has been accepted. The completed sheet 1 of the request will be submitted via normal channels for screening and submitting to data services.

The division officer or designated representative reviews the closeout action, removes sheet 2 from the active file, and forwards sheet 1 to data services via the coordinator. Expeditious submission to data services is imperative in order to produce up-to-date reports. After processing by data services, the repair officer receives sheet 1 of the work request and files it as a record of work requests completed and destroys the previously filed sheet 3.

Error Correction/Deletion Procedures

Error correction procedures are divided into two distinct areas consisting of corrections to planning information and correction to progress information. The critical nature of correction procedure and the resulting impact upon documentation make it necessary that only work center supervisors be allowed to submit correction cards.

CORRECTION TO PLANNING INFORMATION. — Planning information is described as that information submitted to data services on sheet 2 of the work request. Much of this information is prepunched into the daily work supplement cards (4790/2F) and therefore should be closely examined for complete and correct entries. When correction to this information is desired, the work center supervisor will submit a 4790/2K Form to data services, via the coordinator, with the following information:

JCN — Record the JCN of the job requiring corrections.

Make correction entries in only those data blocks that are required to be changed.

On the top right portion of the 4790/2K write the word "correction".

CORRECTION TO PROGRESS INFORMATION. — Progress information is described as that information recorded in blocks A-G of the 4790/2F card. Most of the block A-G information is of a self-correcting nature based on the next card normally submitted. Therefore, the only correction permitted on progress information is the addition or subtraction of man-hours and correction to action taken codes. If correction to progress man-hours or action taken code is desired, a prepunched 4790/2F must be su mitted with the following information:

Block B: ACTION TAKEN. Enter the correction action taken code.

Block C: MAN-HOURS. Enter the hours (to the nearest tenth) to be added or subtracted.

REMARKS. Write the word: "correction" and for block B, enter the previous incorrect action taken code or for block C, indicate either "Add" or "Subtract".

DELETION PROCEDURES. — Deletion procedures are to be used to make corrections and/or deletions when errors in the JCN (UIC, W./C, JSN) or LWC are noted. Corrections to the JCN or LWC are accomplished by submitting a prepunched 4790/2F with the word "deletion" written in the remark section.

Caution is required in making this type correction in that all records (including progress cards) will be deleted from the file. Resubmission of all information using a 4790/2F Form, with correct JCN and/or LWC, is required in order to place the job back in the active file.

MAN-HOUR ACCOUNTING SUBSYSTEM

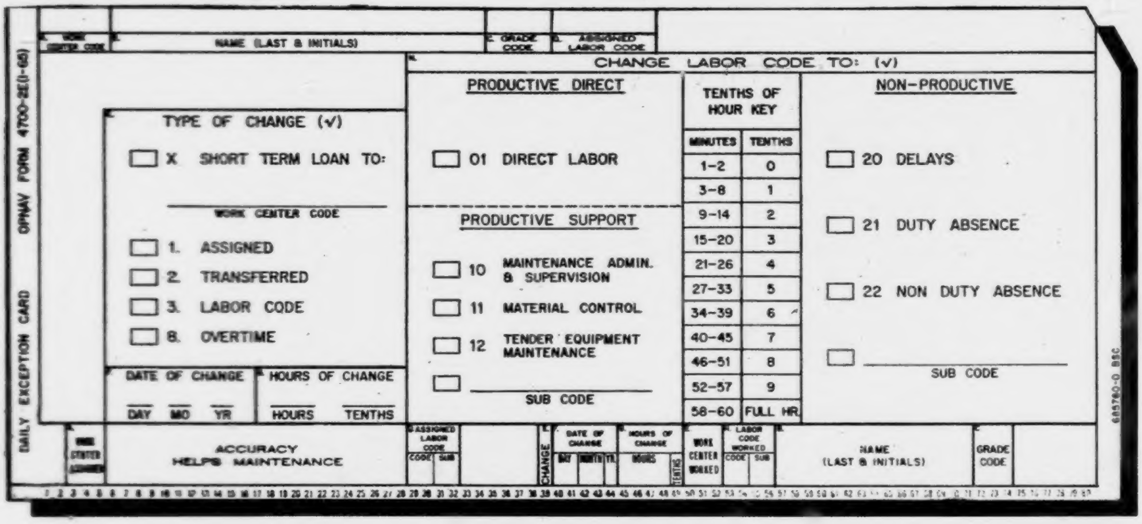
The Man-hour Accounting Subsystem is designed to provide local management with essential man-hour utilization, distribution and assignment information. Effective employment of personnel resources is an important function of command, and the Man-hour Accounting Subsystem provides management with an accurate measure of man-hour employment.

Exception Time Accounting

The Man-hour Accounting Subsystem is based on the "exception principle" wherein each deviation or exception from the normal working day is accounted for and reported. Exception time accounting (ETA) is a term used synonymously for the Man-hour Accounting Subsystem. ETA is intended for use by repair type activities or, more specifically, the repair department of a ship in which maintenance and repair is the primary mission. Basically, ETA will account for the normal seven-hour working day, 0800 to 1600 less one hour for lunch, and for overtime beyond normal duty hours.

ETA complements WLP&C by accounting for the man-hours not documented under the WLP&C. Good management practices using ETA and WLP&C should account for total available man-hours.

When deviations from this ideal situation are necessary, a Daily Exception Card, OpNav Form 4790/2E (fig. 2-7), will be prepared with a ballpoint pen or pencil at the time a person "excepts" from the normal and will be completed at the end of the exception. Only exceptions in excess of 20 minutes (0.3 hr) require the use of an ETA card. When the exception is longer than the scheduled work shift, the card will be completed at the end of the shift and another card will be prepared for the remainder of the exception as an overtime card. The most frequent exceptions requiring the submission of daily exception cards are:



DAILY EXCEPTION CARD OPNAV FORM 4700-2E(1-65)

A. WORK CENTER CODE | B. NAME (LAST & INITIALS) | C. GRADE CODE | D. ASSIGNED LABOR CODE

CHANGE LABOR CODE TO: (✓)

TYPE OF CHANGE (✓)

☐ X SHORT TERM LOAN TO: ______ WORK CENTER CODE
☐ 1. ASSIGNED
☐ 2. TRANSFERRED
☐ 3. LABOR CODE
☐ 8. OVERTIME

DATE OF CHANGE: DAY MO YR
HOURS OF CHANGE: HOURS TENTHS

PRODUCTIVE DIRECT

☐ 01 DIRECT LABOR

PRODUCTIVE SUPPORT

☐ 10 MAINTENANCE ADMIN. & SUPERVISION
☐ 11 MATERIAL CONTROL
☐ 12 TENDER EQUIPMENT MAINTENANCE
☐ ______ SUB CODE

TENTHS OF HOUR KEY

MINUTES	TENTHS
1–2	0
3–8	1
9–14	2
15–20	3
21–26	4
27–33	5
34–39	6
40–45	7
46–51	8
52–57	9
58–60	FULL HR

NON-PRODUCTIVE

☐ 20 DELAYS
☐ 21 DUTY ABSENCE
☐ 22 NON DUTY ABSENCE
☐ ______ SUB CODE

WORK CENTER ASSIGNED | ACCURACY HELPS MAINTENANCE | ASSIGNED LABOR CODE: CODE SUB | CHANGE | DATE OF CHANGE: DAY MONTH YR | HOURS OF CHANGE: HOURS TENTHS | WORK CENTER WORKED | LABOR CODE WORKED: CODE SUB | NAME (LAST & INITIALS) | GRADE CODE

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Figure 2-7.—OpNav Form 4790/2E Daily Exception Card.

Each time a person is assigned to, or transferred from, a work center; each time a person performs work other than that covered by his regularly assigned labor code, each time a person is absent from his work center for nonmaintenance duties such as ship duties, leave, sick cell, or special liberty, and each time a person works more than the normal seven working hours during a single day, or when he works on what is normally considered a "day off" such as Saturday, Sunday, or a holiday.

Daily Exception Card

The daily exception card is designed for automatic data processing and is used to report exception time of each individual covered by ETA.

Labor Utilization Report

The daily labor exception listing, the special labor utilization report, and the three-part monthly actual labor utilization report are the major accounting reports resulting from ETA, and these provide excellent devices for labor utilization analysis.

Exception Time Accounting Codes

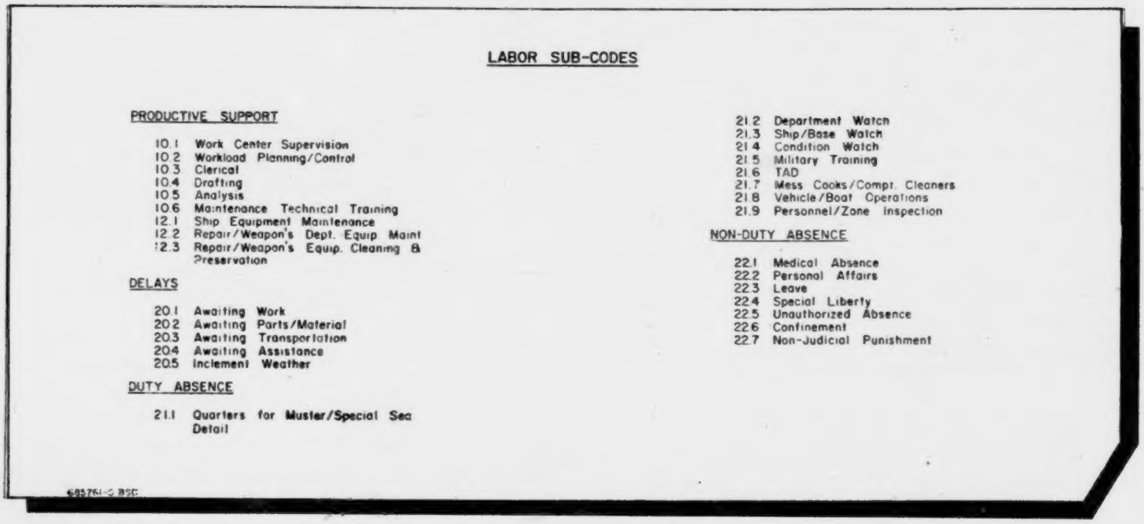
The description codes used in ETA for the preparation of daily exception cards and resultant reports.

WORK CENTER CODES.—Codes for repair activity work centers used in ETA that will identify reporting work centers are contained in section III of the Equipment Identification Code (EIC) Manual. These codes will be entered in block A of the daily exception card.

GRADE CODES.—The following grade codes are prescribed for entry in block C of the daily exception card:

Rank/Rate	Code
E-1	001
E-2	002
E-3	003
E-4	004
E-5	005
E-6	006
E-7	007
E-8	008
E-9	009

LABOR CODES.—Labor codes are provided to account for man-hour expenditures within an



LABOR SUB-CODES

PRODUCTIVE SUPPORT

10.1	Work Center Supervision
10.2	Workload Planning/Control
10.3	Clerical
10.4	Drafting
10.5	Analysis
10.6	Maintenance Technical Training
12.1	Ship Equipment Maintenance
12.2	Repair/Weapon's Dept. Equip Maint
12.3	Repair/Weapon's Equip. Cleaning & Preservation

DELAYS

20.1	Awaiting Work
20.2	Awaiting Parts/Material
20.3	Awaiting Transportation
20.4	Awaiting Assistance
20.5	Inclement Weather

DUTY ABSENCE

21.1	Quarters for Muster/Special Sea Detail
21.2	Department Watch
21.3	Ship/Base Watch
21.4	Condition Watch
21.5	Military Training
21.6	TAD
21.7	Mess Cooks/Compt. Cleaners
21.8	Vehicle/Boat Operations
21.9	Personnel/Zone Inspection

NON-DUTY ABSENCE

22.1	Medical Absence
22.2	Personal Affairs
22.3	Leave
22.4	Special Liberty
22.5	Unauthorized Absence
22.6	Confinement
22.7	Non-Judicial Punishment

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Figure 2-8.—OpNav Form 4790/2E, Reverse side.

organization. The labor codes are divided into three major categories: productive, productive support and nonproductive. Labor subcodes are also provided to enable the maintenance manager to isolate areas where excessive man-hours are being expended. For convenience, subcodes for the major labor code groupings are listed on the reverse side of the daily exception card (fig. 2-8).

Productive Labor Codes.—Only one code is encompassed in this category, Code 01, Direct Labor. Direct labor is labor that is DIRECTLY expended on any equipment (component part, bit, or piece) for which a work center is given maintenance, repair, or manufacture responsibility.

Productive Support Codes.—This category of codes defines labor expended that supports, directs, or controls the direct labor effort. It is frequently referred to as overhead. Productive support comprises Code 10, Maintenance Administration and Supervision; Code 11, Material Control; and Code 12, Tender Equipment Maintenance. The subcodes used in conjunction with productive support codes are prescribed to identify high man-hour consumers if a finer breakdown is desired.

Code 11. Material Control. Charged to this code are man-hours expended in the operation or maintenance of tool cribs and bench or preissue stockrooms; preparation of requisitions; control of inventory; and receiving, crating, or uncrating supplies. Man-hours spent in storage, issue, and material handling will be charged to this code.

Code 12. Tender Equipment/Work Center Maintenance. Man-hours expended maintaining repair department equipment and work centers. This includes man-hours expended performing daily and weekly PMS or preventive maintenance checks; equipment cleaning, servicing, and preservation; cleaning and preservation of work center.

No corrective maintenance or repair will be charged to this code. Corrective maintenance will be documented as 01 labor.

Nonproductive Codes.—Nonproductive labor is labor expended in activities which do not contribute to or support the accomplishment of the maintenance mission; it is, in a sense, lost manpower. The assigned man-hours lost through delay or absence will be charged to these codes, including delay manhours expended during overtime. Nonproductive codes are Code 20, Delays; Code 21, Duty Absence;

and Code 22, Nonduty Absence. The subcodes used in conjunction with nonproductive codes are prescribed to identify high man-hour consumers if a finer breakdown is desired.

Nonproductive codes will not have man-hours assigned.

Code 20. Delays. This code will apply when man-hours are lost from maintenance, and the loss is beyond the control of the responsible work center. Delays in this category are awaiting work, awaiting parts or material, awaiting transportation, awaiting assistance, and delays due to inclement weather. Delays that exceed 20 minutes (0.3 hr) will be charged to this code or the appropriate subcode.

Code 21. Duty Absence. This code applies to man-hours lost when personnel are required to perform duty outside their primary maintenance assignment. Typical absences in this category are watches, working parties, and similar details.

Code 22. Nonduty Absence. Man-hours lost from maintenance while engaged in nonduty activities. This code will include absence such as leave or special liberty.

CODE ASSIGNMENT.—A code will always be assigned to identify the primary job requirement and duty of an individual. Many job assignments require that portions of time be devoted to two or more labor codes. In these cases, the primary job of a person will determine his assignment code. Productive direct and productive support labor codes are the only codes that may be assigned; and when required, subcodes under productive support can also be assigned.

OVERTIME REPORTING.—Overtime man-hours in Code 21, Duty Absence and Code 22, Nonduty Absence are not to be reported. Overtime man-hours are reportable only in Code 01, Direct Labor; Code 10, Maintenance Administration and Supervision; Code 11, Material Control; Code 12, Shop Equipment Maintenance; and Code 20, Delays. When reporting overtime, check the applicable labor code block regardless of the assignment labor subcodes.

Administrative Procedures

The control necessary for man-hour accounting is vested primarily in the work center supervisor. Although each individual responsible for submitting an exception card for himself, when necessary, the success of the man-hour accounting system depends upon the supervisor who ensures that such action is accomplished. The work center supervisor is the primary person for whom the information is collected and is responsible for the accuracy of the reporting. It is of the utmost importance to the effectiveness of the system that you realize and fulfill your responsibility as work center supervisor.

Own Equipment Maintenance

In order to have a reasonable balance between man-hours indicated on progress reports and ETA reports compared to overall man-hours available, personnel documenting under these procedures must be able to report man-hours expended in the upkeep and/or repair of equipments assigned to them for the purpose of performing maintenance for others. This "own equipment" maintenance can be documented in the following manner.

If the job is involved or of such a duration as to need planning estimates, etc, the responsible work center can submit a work request to itself or to other participating work centers. This work request would be estimated, progressed, and closed out in the same manner as a work request submitted from an organizational level activity.

If the job is not involved, or of short duration and does not need planning estimates, etc, the responsible work center may document this work as a completed maintenance action in accordance with MDCS procedures.

MATERIAL CONTROL

The procedures and requirements of material control are applicable to both organization level maintenance ships (DDs, SSs, LKAs, etc) and intermediate level maintenance activities (tender/repair ship, submarine base, etc) and serve to describe the interface between maintenance and supply functions under the 3-M system. The procedures and requirements cover only those materials/parts that are maintenance related. Items such as office supplies, cleaning supplies, forms, and similar items that have no maintenance application are excluded from these procedures and requirements.

The remove-replace-repair concept of maintenance has been adopted by the Navy to reduce the cost of "downtime" or ship and equipments requiring repair of overhaul. Proper management of assets to support this concept is obligatory for maintenance and supply personnel at all levels of maintenance.

The mission of the supply department of intermediate level maintenance activities is to provide material support in the repair of other vessels, self-support, and material support to organizational level maintenance ships as required.

It is mandatory that a supply support center (SSC) be established as part of the supply department. The SSC will be divided into three sections: the supply response section, technical library section, and the material control section. These sections will serve as the liaison between maintenance and supply, will function mainly to meet the material requirements of the organizational and intermediate level maintenance activities.

Rotatable Pools

The primary purpose of the rotatable pool is to provide a facility for the exchange of items of a repairable nature that have been turned into the tender or repair activity for repair. The use of this facility will allow for more rapid response, on the part of the intermediate level maintenance activity, to the requirements of the ships being served. Down time can be reduced and therefore readiness increased, in many cases; by the immediate exchange of a defective item for an operable one.

Preexpended Material

During maintenance work, low cost material such as nuts, bolts, screws and washers are consumed in considerable quantity. The normal issue procedures of such material is costly in terms of manhours and paperwork. The bulk preexpending of such items and their location in maintenance spaces offer significant savings in maintenance manhours by reducing paperwork and waiting time for material. The supply department benefits by a reduced number of issue transactions. Preexpended bins of material are mandatory and will be used to the maximum extent in intermediate level maintenance activities.

Forms

NavSup Form 1250 — This is the single line item consumption/management document. It is a five-part document used to request/issue material internally in ships which do not have automated (mechanized) supply records.

DD Form 1348 (fig. 2-9) — This is the single line item requisition document. It is a four-or six-part form used for internal issue of material in ships with automated (mechanized) supply records. This is the form to be used in instrument shops for maintenance related supply transactions.

Documentation of Material Usage and Cost Data

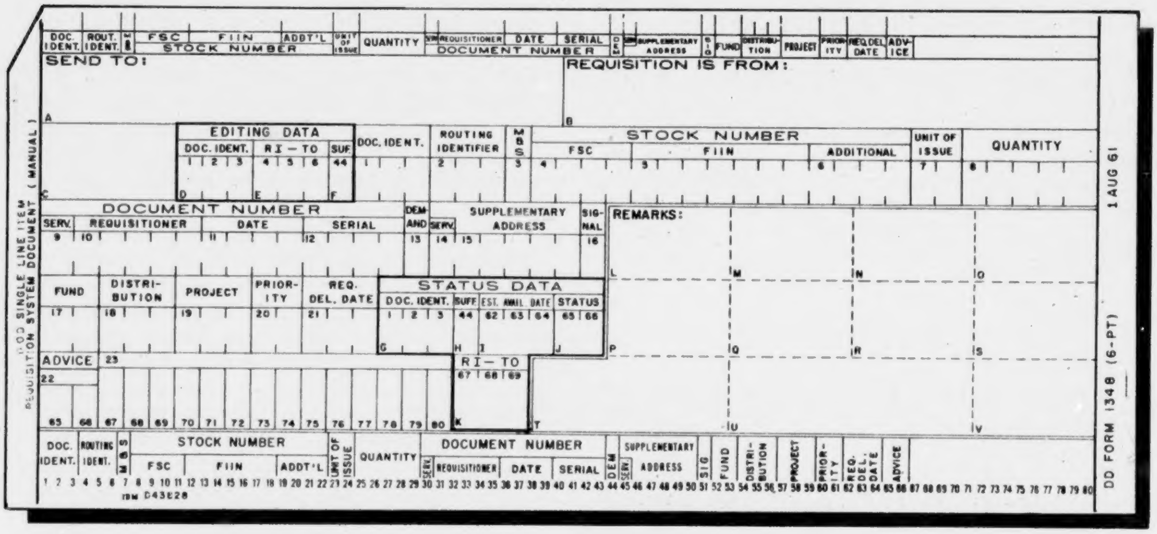
Documentation of material usage and cost data on various maintenance transactions requires the joint effort of maintenance and supply personnel. The maintenance man will initiate documentation for transactions involving requests for material from supply, returning material to supply, and reporting "usage only" for items obtained outside the normal supply channels. Documentation of these transactions will be accomplished by utilizing the single line item requisition document, DD Form 1348.

ISSUES FROM THE SHIP'S SUPPLY DEPARTMENT UTILIZING THE DD Form 1348. -BLOCKS L, M, N. Provide the Unit Identification Code (UIC), Work Center Code (WC), and Job Sequence Number (JSN) from blocks 1, 2, and 3 of the work request pertaining to the maintenance action for which the item is requested. These three codes make up a unique number called the job control number (JCN). Care must be exercised to ensure the same JCN is used on all supply documents relating to the same maintenance action.

Blocks 4, 5, and 6: STOCK NUMBER. Provide the Federal Stock Number (FSN) for all items requested when possible.

Block 8: QUANTITY. Provide the actual quantity required, consistent with the unit of issue, to complete the maintenance action.

Blocks 10 and 11: DOCUMENT NUMBER. The document number will contain two data elements: in block 11 the Julian date of the day that the request for an item was placed with the supply department; in block 10 the next sequential department/division serial number for each transaction.


DOC. IDENT.
ROUT. IDENT.
M&S
FSC
FIIN
ADDT'L
STOCK NUMBER
UNIT OF ISSUE
QUANTITY
SERV.
REQUISITIONER
DATE
SERIAL
DOCUMENT NUMBER
DEM
SUPPLEMENTARY ADDRESS
SIG
FUND
DISTRIBUTION
PROJECT
PRIORITY
REQ.DEL. DATE
ADVICE
SEND TO:
REQUISITION IS FROM:
A
B
C
EDITING DATA
DOC. IDENT.
RI — TO
SUF.
D
E
F
DOC. IDENT.
ROUTING IDENTIFIER
M S
STOCK NUMBER
FSC
FIIN
ADDITIONAL
UNIT OF ISSUE
QUANTITY
DOCUMENT NUMBER
SERV.
REQUISITIONER
DATE
SERIAL
DEMAND
SERV.
SUPPLEMENTARY ADDRESS
SIGNAL
REMARKS:
L
M
N
O
FUND
DISTRIBUTION
PROJECT
PRIORITY
REQ. DEL. DATE
STATUS DATA
DOC. IDENT.
SUFF.
EST. AVAIL. DATE
STATUS
G
H
I
J
P
Q
R
S
ADVICE
RI — TO
K
T
U
V
DOC. IDENT.
ROUTING IDENT.
M&S
STOCK NUMBER
FSC
FIIN
ADDT'L
UNIT OF ISSUE
QUANTITY
DOCUMENT NUMBER
SERV.
REQUISITIONER
DATE
SERIAL
DEM
SERV.
SUPPLEMENTARY ADDRESS
SIG
FUND
DISTRIBUTION
PROJECT
PRIORITY
REQ. DEL. DATE
ADVICE
IBM D43E28
DOD SINGLE LINE ITEM REQUISITION SYSTEM DOCUMENT (MANUAL)
DD FORM 1348 (6-PT)
1 AUG 61

43.24

Figure 2-9.—DD Form 1348.

Block 20: PRIORITY. Provide a single alphabetical code only on items that are not-in-stock (NIS) or not-carried (NC). The code shall be a realistic code assigned by responsible personnel designated by the department head.

Block 21: REQUIRED DELIVERY DATE. Provide a Julian required delivery date (RDD) only on items that are NIS or NC, and only then when it is imperative for the item to be onboard by a certain date in order to complete maintenance to meet a ship's operating schedule.

Blocks L, M, and N: Enter the UIC, WC, and JSN. This Job Control Number must be identical to that of the associated 4790-2K.

Blocks P and Q. Provide the equipment identification code from the EIC Manual.

Blocks R and S. Provide the APL/AEL code from the work request. In cases where an APL/AEL does not exist, enter "NOT LISTED."

Block U. For all electronic/ordnance items, provide the reference/circuit symbol. This symbol may be found in schematics, circuit diagrams, technical manuals, weapons publications, etc. For hull/mechanical/electrical items enter the noun name using standard abbreviations where necessary, not to exceed 10 characters. Further documentation of the DD Form 1348 will then be accomplished by supply personnel as set forth in appropriate supply directives. After appropriate action has been taken by supply, the maintenance man will receive a copy of the DD Form 1348 with the material. In cases where the material is not available onboard, the work center will be provided a copy marked NIS or NC as appropriate for the work center's status information.

Usage Only Reporting

When a part is required to complete a maintenance action and is obtained from sources other than supply (items such as from cannibalization, salvage or stripping a ship or local manufacture), it is imperative that the data on the part be documented on a DD 1348 as follows:

Block A: SEND TO. Write the words "Usage Only" in this data block to ensure proper reporting of item used.

Block V. Provide the maintenance source code in this block to ensure proper reporting of source of item used. Information in blocks 20 and 21 is not required. Usage of preexpended bin material will not be reported. Further documentation of the DD Form 1348 will be accomplished by supply personnel as set forth in appropriate supply directives.

Replenishment of Preexpended Stocks

Replenishment of preexpended bins at intermediate level maintenance activities is the responsibility of the supply support center. Maintenance personnel responsibilities include only security to prevent pilferage and housekeeping requirements in the bin areas.

QUALITY CONTROL

Present shipyard calibration programs are designed to ensure that 95.4 percent of measuring and test equipment is within tolerance when returned at suggested calibration intervals. Although present calibration intervals may be a satisfactory compromise between cost and efficiency, there still exists out-of-tolerance measuring and test equipment having an in-date calibration status. When this equipment is used, it will be necessary to remeasure or retest the work with accurate equipment.

Relying on the present calibration program with recall cycles of six months or longer to learn that instrumentation is out-of-tolerance at calibration and that remeasurement or retest is necessary is of little benefit because, in many cases, there is no way of knowing when the measuring or test equipment went out-of-tolerance, detailed usage records are needed to determine what products have been measured or tested with a particular instrument, and most products are assembled or installed making remeasurement or retest impossible or economically prohibitive. Therefore, to determine whether measuring and test equipment is out-of-tolerance at the time it is used, an early detection system is needed.

CROSS-CHECK SYSTEM

The cross-check system can provide a positive means for identifying out-of-tolerance equipment before it is used and can certify that the test or measuring equipment was in necessary tolerance during its use.

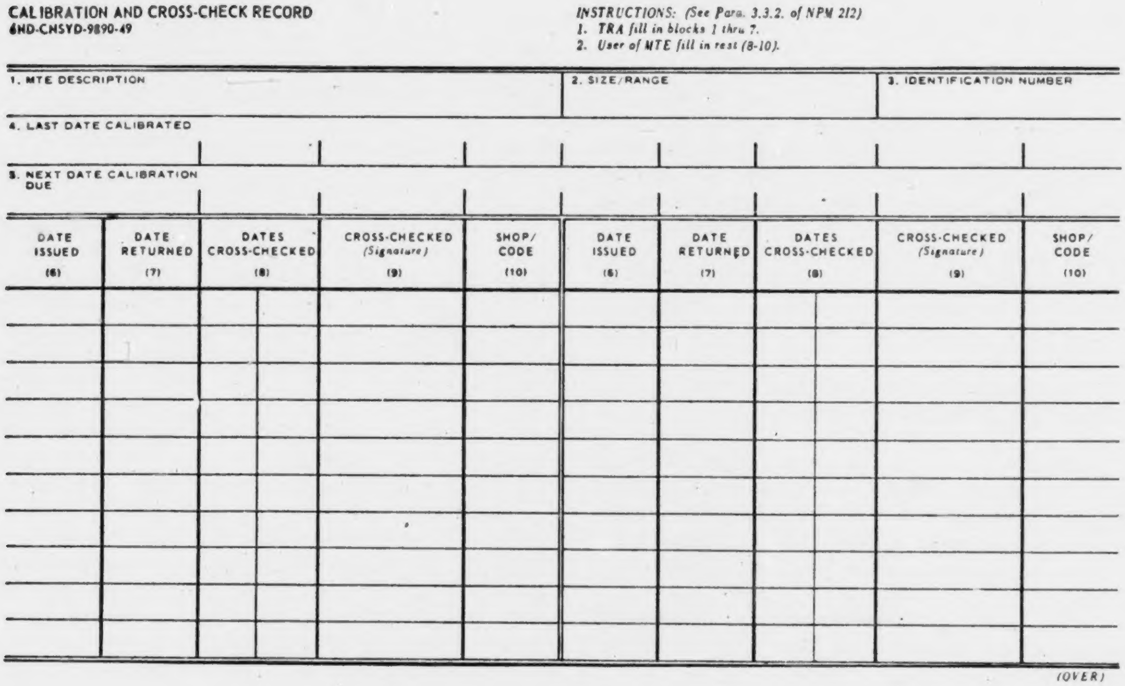
Cross-checking is simply comparing two or more instruments of equal or near equal accuracy to determine whether the readings of the instruments differ significantly. For purposes of these instruments, it is the comparison of an instrument with a specified tester or standard. The comparison need only be an accuracy check for the range of measurements for which the instrument was, or will be, used. The cross-check system is applicable to measuring and test equipment used to determine the acceptability of a physical characteristic of a component or system such as pressure, dimension, torque, voltage or amperage.

First, in establishing a cross-check system, a set of standards must be procured which will cover the physical characteristics and range of the measuring and testing instruments frequently used. Instruments which see very infrequent usage should be maintained in a status of "calibrate before use" and should be calibrated immediately before use and checked for accuracy immediately after use by the appropriate calibration facilities. These instruments should not be considered part of the cross-check system.

Secondly; a series of cross-check procedures should be prepared providing a step-by-step procedure explaining how the instruments are to be checked for accuracy.

The user is responsible for cross-checking his measuring or testing equipment and recording the results on an appropriate form such as the Calibration and Cross-Check Record (fig. 2-10). The toolroom attendants should not authorize issue or return of measuring and test equipment under their responsibility unless the required cross-check has been performed. Violations should be immediately reported to the repair shop supervisor. As noted earlier, the user need only check for accuracy for the range of measurements for which the instrument was, or will be, used. For example; a torque wrench need only be tested for the setting at which it will be used, the electrical or electronic instrument only for the range, frequency, etc. at which it was, or will be, used. If the user finds an instrument which appears to be out-of-tolerance, the instrument should be immediately forwarded to the appropriate calibration facility for verification.

Measuring and test equipment need not be cross-checked after each individual measurement. Measuring and test equipment is cross-checked when issued and again when it is returned to the toolroom. To minimize the possibility that the tool will go out-of-tolerance before use, the initial cross-check should be



CALIBRATION AND CROSS-CHECK RECORD
6ND-CNSYD-9890-49

INSTRUCTIONS: (See Para. 3.3.2. of NPM 212)
1. TRA fill in blocks 1 thru 7.
2. User of MTE fill in rest (8-10).

1. MTE DESCRIPTION
2. SIZE/RANGE
3. IDENTIFICATION NUMBER
4. LAST DATE CALIBRATED
5. NEXT DATE CALIBRATION DUE

DATE ISSUED (6)	DATE RETURNED (7)	DATES CROSS-CHECKED (8)	CROSS-CHECKED *(Signature)* (9)	SHOP/ CODE (10)	DATE ISSUED (6)	DATE RETURNED (7)	DATES CROSS-CHECKED (8)	CROSS-CHECKED *(Signature)* (9)	SHOP/ CODE (10)

(OVER)

91.420

Figure 2-10.—Calibration and cross-check record.

done within a reasonable time before use. All cross-checks after use may be accomplished within a time frame which will permit remeasurement or retest if the cross-check reveals the instrument to be sufficiently out-of-tolerance.

When a calibration facility finds measuring and test equipment out-of-tolerance during a routine calibration, they should notify the toolroom responsible for the issue of the tool. The toolroom attendant should then verify the Cross-Check Records to ensure that the tool issued was cross-checked after use. If the tool was satisfactorily cross-checked after use, it is assumed that the out-of-tolerance condition occurred after the measurement and no further action is required. If cross-check was not recorded or performed, the toolroom notifies the shop supervisor. He investigates the use of the tool and ensures appropriate corrective action to correct any defects produced by the faulty tool.

JOB PLANNING

Good planning is the process of sizing up the job to be done and determining effective methods and procedures for completing the project. One good way to plan a job is to define as accurately as possible the work to be done. Then, you predict any possible problems that will arise. Finally, you make decisions and take action to solve or correct those anticipated problems.

TASK DEFINITION

To get an assigned job done in the proper manner and on time requires careful planning. You will need to know exactly what is to be accomplished, when it must be completed, the number of men available to do the job, and the amount of material required. In addition you will need to coordinate your work with men in other ratings. In any event, you must study all available information carefully to be certain that you understand all important aspects of the job to be done.

PLANNING HINTS

As the petty officer in charge, you are responsible for the time of your men as well as for your own time. You must plan so that they will be kept busy doing constructive work. Planning should be done at your convenience, but it must be pointed out that keeping the men in the shop each morning doing nothing while you plan is a waste of manpower. At the close of each day, you should confirm planning for the next work day.

Have the manpower, equipment, and supply situations been examined thoroughly?

1. Manpower. Who is to do what? How is it to be done? When is it to be finished? Knowing that idleness may breed discontent, have you arranged to have another job ready for starting as soon as the first one is finished? Is every man fully utilized?
2. Equipment. Are all necessary equipment and tools on hand to do the job? Is safety equipment on hand?
3. Supplies. Are all necessary supplies on hand to start the job? If not, who should take action?

Have a definite work schedule and inspection plan. Set up goals or quotas for the day. Have a definite plan for personally checking at intervals to see that the work is being accomplished and that the goals are going to be met. Spot-check for accuracy, workmanship, and the need for training.

Until a petty officer learns to delegate work properly, he can never be much of a success. Every time you find that a job has become routine, set up a simple procedure. Train someone to handle the job, and from then on let that person handle it.

In delegating authority, be sure that the man concerned has the training and information necessary to carry out the work. If you find that he cannot do the job that is required, he may have to be retrained. Remember, you can delegate your authority, within reason, to subordinates; but you cannot delegate your responsibility for the final product.

Instrumentmen must be trained to do a variety of jobs by means of the rotation method, on-the-job training, or classroom work; allow time for this in your planning for a job. Time must also be allowed for handling personnel problems, records and military duties. A supervisor must allow time for reports and other paperwork necessary for the control of men and materials under his charge.

SCHEDULING AND COORDINATION

The various phases of a job must be carefully scheduled if it is to progress without delays. Generally speaking, the sequence of work assignments must correspond to actual operations. You must remember, of course, that some jobs take longer than others to complete. Perhaps one man could be assigned to partially assemble one section of a typewriter, while another man is still working and repairing or replacing a defective component of the typewriter.

It is important that every man assigned to you knows his job and how it fits into the schedule or knows what jobs are being scheduled for him. In some cases, a man may not be familiar with all phases of the job to which you assign him; for instance, a man may have had no recent experience working with calibration of a Yarway remote liquid level indicator. If he is assigned to that calibration job, knowing this in advance would give him a chance to brush up on this type of work. Making up the schedule in advance and posting it on the bulletin board or in some other prominent place is a useful method of keeping your men informed of their forthcoming assignments.

Successful planning may be accomplished by careful day-to-day thinking and alertness on the job, and accurate work element, manpower, material, and equipment estimates. In addition, material delivery and storage arrangements, and accurate work schedules laid out under strict progress control charts which are checked continuously, will increase the possibility of completing the assigned job safely, accurately, and on schedule. Remember, all the items discussed above are dependent upon each other. The greater the detail and care you take in planning, scheduling, and coordinating, the better are your chances for success.

Personnel

Failure to make allowance for personnel changes can slow down work or cause a complete stoppage. Some personnel matters, of course, are beyond your control. If a man suddenly becomes ill or goes on emergency leave, you will simply have to try to get a replacement for him or do some rescheduling. If a man is scheduled for leave or for detachment, however, and you do not take this fact into consideration when planning your schedule, the fault for any delay which results lies with you. In making up your schedule, consider military duties, special details, and similar factors that could affect work operations.

If you have a shortage of men for the job—and this is not unusual—be certain that you assign them to best advantage, according to their skills and capabilities. Never ask for more men than you can use on a job; extra men get in the way of the workers.

Material

When major projects are to be undertaken, check past expenditures to obtain a guideline which will help you keep an adequate inventory of parts and material. Materials should be checked during the planning stage to make certain that all materials are available or are on order. Even with this check, there is sometimes danger of running out of material. This may happen when the rate of progress on the job has been considerably greater than anticipated or when materials have been unusually slow in arriving at the job. If either of these conditions occur, notify the officer in charge of the project. He may appoint an expediter to see that materials get to the location where they are needed. Occasionally, you might hand-carry a requisition through the supply chain to speed up delivery. This is strictly an emergency procedure, however. Careful advance planning will normally ensure an orderly flow of materials.

Machinery and Equipment

Machinery and equipment failures may result from numerous causes, many of which can be prevented. See that your men follow proper operating and maintenance procedures. Manufacturers' instruction books and local instructions should be strictly followed.

Instruction Manuals

Instruction books are issued by the manufacturers to guide you when you have to repair any defective equipment. They contain descriptions of the theory of operation, photographs, schematics, troubleshooting hints and lists of component parts, among other pertinent information.

You have seen them, but many of your younger men may never have seen them. Perhaps a lesson on the organization of one of these manuals might be a good idea for a training session. Show your men how diligent use of the manual will be advantageous to them in expediting repairs accurately and safely.

These manuals should be filed alphabetically or numerically according to the NAVSHIPS number assigned to each piece of equipment and cross-referenced. BE SURE YOUR MEN KNOW THE IMPORTANCE OF SAVING AND RETAINING THESE MANUALS IN GOOD SHAPE. Frequently they are your only guides to the accurate operation and repair of equipment.

TRAINING

Most large, successful, companies recognize that the most important responsibility a supervisor has is that of achieving a well-trained work force. Why is this important? Proper training results in fantastic improvements in production, quality, safety and morale and reduces costs due to spoilage. When a new man reports to the ship his entire attitude toward the Navy may be influenced by those in charge at this duty station. Proper training will point the man in the right direction. You can see the advantages of proper training if you note the time it takes to correct mistakes, the costs involved, and the necessity for reassigning work loads and other schedules. Wouldn't it be simpler to train the men properly in the first place?

Many supervisors have said to themselves that they had no time for training their men. The supervisor who has difficulty finding time to train his men is probably being overworked because the men are not properly trained. If the men are trained properly, then the supervisors can devote most of their time constructively to Planning, Organizing, Directing and Controlling.

RESPONSIBILITIES

As a senior petty officer you should recognize your responsibilities as you plan and organize your unit for training purposes. The following information may be useful.

1. Identify the equipment and jobs for which you and your men are responsible.

2. Determine the requirements for each job with respect to the knowledge and skills required for successful completion.

3. Analyze the qualifications of each individual under your supervision to determine the qualifications he already possesses. An excellent source of information for this is the man's service record and his training record. Further information may be obtained from the man by a personal interview. Always remember, however, that he may respond with answers that he thinks you want to hear. Perhaps the best way is to simply observe the man as he performs various tasks assigned to him.

4. Compare each individual's qualifications with the job requirements. The difference between his qualifications and the actual requirements of the job indicates that man's training needs.

5. Make provisions for fulfilling the individual's training.

6. Train personnel responsible for instruction. Be sure to indoctrinate all personnel involved in the importance of training and the advantages and needs for developing a force of well-trained Instrumentmen whose operating capabilities will be at a near peak condition because of this training.

Now that you have planned and organized your training you should also recognize one of the other important functions a good supervisor must have. Don't you agree that control is a vital link in the managerial process? Therefore, you should observe the training to determine the effectiveness of the training methods and techniques. Are they correct and complete? What additional training aids and materials are required? Can I obtain some equipment for training use? What are the equipment for training use? What are the reactions of the trainees? Are they showing interest and performing with enthusiasm or are they just sitting around in the classes? How about holding conferences with the instructors to discuss their findings and suggestions? Frequently the students themselves offer good suggestions. Be sure to let them know that these suggestions are welcome.

Another effective method for achieving control of training and instruction is to check the training progress cards for accuracy and completeness.

Remember that training is a vital, never ending process which may be formal or informal and provides us with tools for raising the operating efficiency and development of all personnel. Training will be more effective if adequate CONTROL measures are taken.

PURPOSES

Training includes all of those formal and informal situations where individuals or crews are given instruction toward the solution of:

1. Immediate problems related to the readiness of the unit to perform its current mission, or the problems related to the readiness of the members of the unit to do their jobs with a high degree of skill.

2. Long-range problems related to the readiness of members of the unit to qualify for advancement in rating, or the problems encountered when members of the unit need training for future jobs requiring skills not now possessed.

ADMINISTRATIVE GUIDELINES

Most shipboard training is administered at the division level, with the more senior petty officers carrying out the training program and teaching the lessons. The training should be consistent with the following guidelines:

1. It must be closely integrated and coordinated with the daily operations of the shop. The plan and organization for training must not interfere with the essential repair and maintenance functions.

2. Concentration on the job schedule should not be so extreme that opportunities for training are overlooked; some types of training may even have an immediate beneficial effect on the job.

3. Maximum advantage should be taken of the opportunities to derive training benefits from routine operations.

The training of Instrumentmen in the proper use of equipment in the shop is your responsibility. Provide the training essential for each man before you authorize him to use a machine. An improperly trained machine operator can soon damage an expensive machine. A careless or indifferent attitude by an Instrumentman relative to the operation of a machine should not be tolerated. Responsibility for proper care and usage of shop equipment actually rests with the shop supervisor, the person responsible for training, and not with the operators.

One important aspect of training is on-the-job instruction; and this must be individualized for each person and each job. Training of an Instrumentman in the repair of a cash register, for example, or anything new to him, must be accomplished on an individual basis and by degree. If a man knows how to repair one watch or electric typewriter of a specific make and model, of course, he will know something about repairing similar machines of different makes and models.

The best way to teach a person by the on-the-job method is to demonstrate slowly and methodically, with appropriate explanations, the procedure for doing a certain thing. Then repeat the same thing and have the trainee explain to you how to do it. Then have the trainee do the work while you supervise him and correct deficiencies in his procedure and/or technique. From this point on, much practice in doing the work leads to proficiency.

A study of the job skills required to do a future job may be the starting point for training. After you have made such a study, take an inventory of the skills the men in your crew now possess. You can easily see whether the required skills match the available skills. When you cannot match the skills, you may have to conduct training sessions in order to bring the men up to the proficiency required to do the job. In some cases you will have to conduct refresher training; in other cases you will have to provide instruction in new techniques for doing things.

At the shop, for example, much of the training will be for the purpose of helping a man become more versatile, so that he can fill more than one job. One man might be a good calculator repairman but lacks training in the field of watch repairing. On the other hand, some training may help him do his present job better.

To do your own job properly, you must study and work continuously to improve your own techniques. You must analyze work procedures and find ways to combine operations to shorten the time required to do a job. Having done this, you must train your men in the new procedure. Take advantage of the individual's own concerns and motivation as you proceed.

Individual Concerns

Shipboard training will have two objectives: to assist men in increasing their proficiency so that they can advance and assume greater responsibilities, and to assist men in increasing their proficiency so that the ship, the department, or the division can perform better.

The Navy enlisted man is usually interested only in training that has a real, immediate objective. He is interested in information and learning, only insofar as he can see the attainment of a goal whereby he can advance himself in his own eyes and in the eyes of his shipmates, friends, and relatives. Consciously or unconsciously, the man will, from time to time, evaluate his progress in these terms, and your training program must be able to supply the means for achieving this goai if training is to remain meaningful to him. Once the program has lost the immediate objective in the eyes of the man, his motivation will disappear, and with the loss of motivation he loses the prime mover in the whole process of learning.

Learning takes place in relation to what the student already knows; it must tie in with the whole and be considered a part of the entire pattern of the man's knowledge. The new must be built into the old.

A man's learning should be followed by his being able to use the new knowledge in a practical, working manner. This principle is true in adult education and in vocational training, both of which characterize the Navy training problem; the men have little interest in subject matter for which they cannot see an immediate, practical, and functional application.

CARRYING OUT AN INSTRUCTIONAL PROGRAM

Remember—a successful training program can be successful only if those at the top (you) take the program seriously. Very rarely will one of the trainee take the program seriously if a mockery of the training program is made at the top echelons. You recognize the terrific shortage of competent technical personnel. Take the appropriate steps to relieve that problem by training your personnel. Remember—the purpose of your training should be to not only teach a man a particular job, but also to stimulate the trainee so that he has a desire to learn and improve himself as you shape his attitudes toward doing a better job.

Take advantage of any programmed instructional material you may have access to. The Catalog of Programmed Instructional Material, NavPers 93286A tells you where to obtain such material.

Be sure to send your men to various Navy schools as the quotas permit. Remember too, that men may also be sent to some of the manufacturer's schools for special training. Take advantage of this opportunity if presented to you or your men. When a man comes back from the schools be sure that he has the opportunity to pass on the information he has acquired to the other men as well as yourself.

Your ability to carry out an instructional program economically, efficiently and continuously will be enhanced if you are familiar with ON-THE-JOB TRAINING (OJT) and FORMAL TRAINING. OJT is practical training conducted as part of the normal routine of work. Formal training is done during special training sessions, schools or with the use of materials such as text reading assignments, or programmed instructional materials. Your knowledge of various tests and the purposes they serve will enable you to prepare your men so they can better understand their own deficiencies. You will also be able to evaluate your training program from the results of these tests. Finally, your ability to classify subject matter into various types will enable you to decide appropriate training methods.

Two types of tests are available to you. The one you will use most is the performance test. This is a test of job skill, and the trainee demonstrates his proficiency by doing the actual job. The other type of test is a written test, and probably is not available unless you have special channels to obtain this from Navy schools. However, you can tell from how your men do on an advancement exam how good your training program is.

CLASSIFICATION OF SUBJECT MATTER

The Navy classifies its subject matter into three types: KNOWLEDGE, SKILL, AND ATTITUDE. How you organize and conduct training depends upon what you want or must teach. There is no "best" method. Training on-the-job is different from training in a formal, classroom situation, although there are some common techniques.

Knowledge Type

Knowledge-type subject matter is that which is taught to build up a store of useful facts, principles, theories, and so on. This type of subject matter is usually presented in a formal training situation. Temperature measuring theory, for example, is knowledge type subject matter. Common properties of electrical circuits is also knowledge type subject matter. Instruction in these, and other such subjects, would probably not begin on the job. After theory and principles are developed, however, their application might well be demonstrated either under formal conditions or in an on-the-job training situation.

A training manual such as Instrumentman 3/2, NavPers 10193-C, provides the men with knowledge type subject matter. The correspondence course that accompanies it carries questions to determine how well they have gained the information. Encourage your men to complete their correspondence courses.

Skill Type

A skill type subject — mental or physical — is subject matter taught to help a man acquire an ability to perform required jobs with ease, speed, and precision. The teaching approach to this situation would, of necessity, be quite different from a knowledge-type instructional situation. Skill type instruction is usually the next step in instruction following the presentation of knowledge type instruction; or it may be instruction born of necessity on the job. Additionally, it may be skill training planned by an IMC to see if a striker who has read a chapter on manual typewriter repair can actually repair such a typewriter.

If need for instruction in a skill type subject grows out of a job, it may be taught on the job, or it may require instruction (as least for introductory information) under formal conditions. Later, an on-the-job training situation may be appropriate for application and practice of acquired skills.

Attitude Type

Attitude type subject matter is selected and taught to create proper feelings, understandings, respect, etc. Safety precautions could be attitude type; so could military courtesy. Both might be knowledge type, too. "Seabee Accomplishments" is an attitude type subject.

Attitude type subject matter can be organized in the same manner as knowledge type subject matter.

CATEGORIES OF TRAINING

Categories into which training is classified, at least for the purposes of this chapter, are ON-THE-JOB training and FORMAL training. These categories, together with hints for conducting such training, will be discussed briefly in the remaining pages of this chapter.

On-The-Job Training

On-the-job training is mainly for the men who already have skills and are on the job. It is usually controlled through daily job assignments.

In general, the objectives of on-the-job training in the Navy are: to broaden a man's work experience, to improve his work methods and increase his production, and to provide training for him in the application of basic skills to specific work assignments. It is also used to make a check on a man's skills as well as his understanding and proper observance of safety precautions.

PETTY OFFICER EQUIPMENT SEMINARS. —Some of your petty officers have especially good knowledge about certain equipment. Take advantage of this and ask them to impart their knowledge to the other men, especially the quirks and peculiarities of the equipment that they have learned by experience. Be sure that the trainees understand that they should ask as many questions as they wish pertaining to the equipment and that they know that the "only stupid question is the unasked question." Impress unpon the instructors the necessity and importance of training the men properly.

TRAINING DRILLS.—What should a man do if there is a fire? Does he know the procedure to follow?

Can he repair or replace a defective component quickly and safely? Going through the procedure to be used if a simulated casualty occurs will enable a man to perform the required steps he must take expeditiously and with confidence.

Formal Training

Training requirements which grow out of a job, but which cannot be taught on the job, may require a formal, group instructional setting. It generally takes place during regularly scheduled training periods during the work day, and it may or may not be voluntary on the part of the trainees participating.

PURPOSES.—Formal training may be arbitrarily divided into two areas:

1. Subject matter required for advancement in rating. Here the instructing petty officer conducts training in general subject matter areas such as mathematics, blueprint reading, or basic electricity. In this training situation men from other ratings may also participate, since knowledge in mathematics, for example, is a requirement for several ratings. At other times, in connection with advancement in rating, refresher training is required. Here the teacher instructs men from various ratings in subjects required for promotion. He may discuss Bourdon tube theory or a variety of gage applications, etc.
2. Subject matter required for the solution of an immediate problem which may or may not have a bearing on rate training. On one ship installing a MIRCS some of the men did not know the appropriate procedures to use.

The IMC obtained and taught the required procedures. This situation occurred when the first MIRCS was installed aboard ship and knowledge of these procedures was not yet a "qual".

PRACTICAL SAMPLE.—The presentation and suggestions about to follow are included to give you ideas of how you might carry out an instructional program. The hints given are not to be constructed as standards one is bound to observe.

During the planning stage of any training, the following actions on your part are necessary:

1. Ascertain what the training requirements are.
2. Prepare an outline of instruction.
3. Determine the training aids, materials, and equipment that you will use.
4. Prepare lesson plans, lecture notes, and instruction sheets to complement the instruction.

OUTLINING THE INSTRUCTIONS.—Having learned what the training requirements are, perhaps the first bit of planning is in connection with the preparation of a complete outline of the scope of the instruction. One method of preparing such an outline is to make a quick survey of the subject matter field. Review the Navy rate training manuals bearing on the subject. After this survey, broad areas of instruction will begin to shape up in your mind.

Within each of the broad areas identified for training, the next step is to develop topic outlines, and arrange them in a systematic manner, so that each topic and subtopic within the outline rests securely upon information developed in a preceding topic. For example, you might wish to teach the men basic electrical circuitry so that they will better understand thermocouples, millivolt potentiometers, and electrical safety. You may arbitrarily decide that one topic within the broad topic of "Direct Current Circuits" might be "Direct Current Series Circuits." Another might be "Ohm's Law." A partial outline of instruction might appear as follows:

1. Direct current series circuits
   - a. Series circuit connections
   - b. Resistances in series
   - c. Current flow in series circuits
   - d. Voltage in series circuits
   - e. Demonstration of series circuits

     (1) Series circuit resistance
     (2) Series circuit current
     (3) Series circuit voltage
     (4) Open circuits
     (5) Short circuits

2. Ohm's Law
   - a. Ohm's law in simple circuits
   - b. Ohm's law in series circuits
   - c. Ohm's law demonstrated
   - d. Experiment on Ohm's law

After subject matter is selected, but while a detailed outline is being prepared, make a list of all training aids, special devices, equipment and tools which will be useful in teaching. If instruction is to take place at a time in the future which permits ordering training film, transparencies, and other training devices, include these in the list.

Before, after, or concurrently with the development of the training aids and equipment list or the outline of instruction, make a list of all texts and instruction books that are to be used in preparing for and in presenting the lessons.

Based on the outline of instruction, the instructor next develops lesson plans for specific training periods.

LESSON PLANS.—A lesson plan is the blueprint the instructor uses to teach a specific topic or lesson. When the planning previously discussed has been accomplished, a lesson plan is not difficult to prepare. Lesson plans can be in many forms. The following main parts of a lesson plan have been used in Navy training for many years: title of topic, objectives, training aids, references, introduction, presentation, application, summary, test, and assignment. A format for use in preparing a lesson plan is given in figure 2-11.

It will be observed in figure 2-11 that the instructor is cued to do certain things at certain times. Directly opposite or immediately below various points in the outline of instruction in the presentation section of the lesson, the instructor includes methods he will use to teach, questions he will ask, or problems he will work.

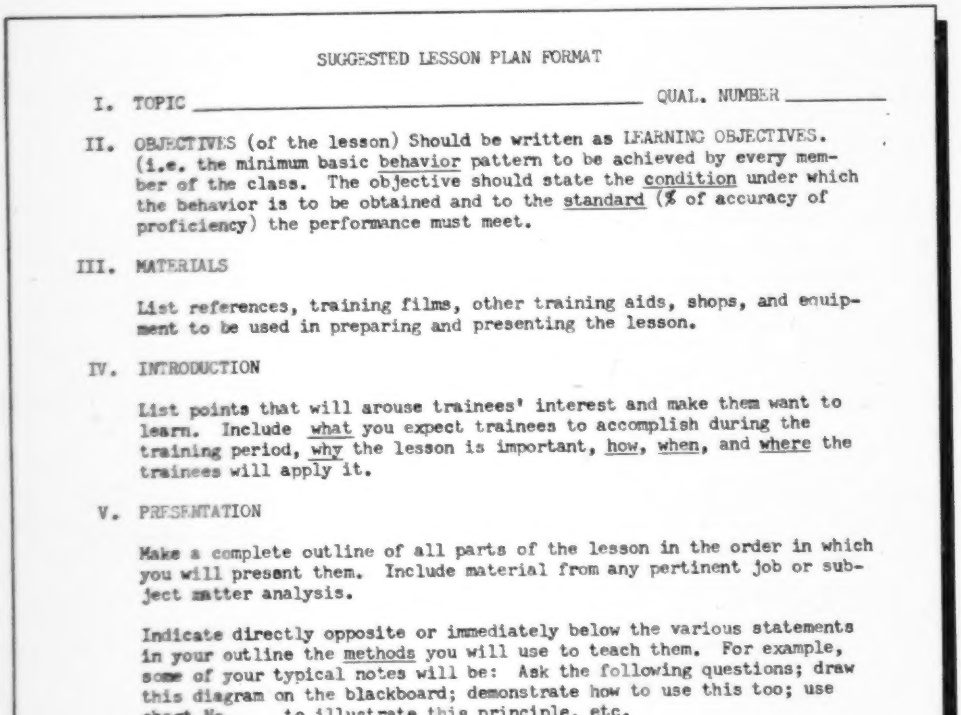
It is presumed that when one teaches he is thoroughly trained and already has acquired the technical information he expects to impart to the class. He may, nonetheless, in advance of his presentation, prepare his own lecture notes which will parallel, as necessary, the points in his lesson plan. Figure 2-12 shows a partial set of lecture notes on the Electron Theory which the instructor might want to prepare and refer to as he teaches.

INSTRUCTION SHEETS.—To augment the teaching and to complement the lesson plan, the resourceful instructor may enrich his teaching by using instruction sheets.

Several types of instruction sheets are used in Navy training:

1. Information sheets
2. Job sheets
3. Assignment sheets

These sheets are instructor made and are designed to assist the trainee in the learning process. They may be planned for in the lesson plan as a part of formal instruction, or be used in a self-study situation where the time the instructor can give individual instruction is limited. Information sheets are developed when a knowledge-type subject has been introduced and the instructor desires to give the trainee information that he must know in order to do a



SUGGESTED LESSON PLAN FORMAT

I. TOPIC ______________________ QUAL. NUMBER __________

II. OBJECTIVES (of the lesson) Should be written as LEARNING OBJECTIVES. (i.e. the minimum basic behavior pattern to be achieved by every member of the class. The objective should state the condition under which the behavior is to be obtained and to the standard (% of accuracy of proficiency) the performance must meet.

III. MATERIALS

List references, training films, other training aids, shops, and equipment to be used in preparing and presenting the lesson.

IV. INTRODUCTION

List points that will arouse trainees' interest and make them want to learn. Include what you expect trainees to accomplish during the training period, why the lesson is important, how, when, and where the trainees will apply it.

V. PRESENTATION

Make a complete outline of all parts of the lesson in the order in which you will present them. Include material from any pertinent job or subject matter analysis.

Indicate directly opposite or immediately below the various statements in your outline the methods you will use to teach them. For example, some of your typical notes will be: Ask the following questions; draw this diagram on the blackboard; demonstrate how to use this too; use chart No.____ to illustrate this principle, etc.

List questions on key points to be asked in order to stimulate trainee thinking and to determine trainee understanding and learning.

VI. APPLICATION (by the trainee)

Indicate in your outline the activities that you will have the trainees actually do during the lesson to apply it. Typical notes could include: Have all trainees solve the following problem; select a trainee to assist in demonstrating this operation; have all trainees perform training in the practical factors where required.

VII. SUMMARY

Recapitulate main points to strengthen the instruction.

VIII. TEST

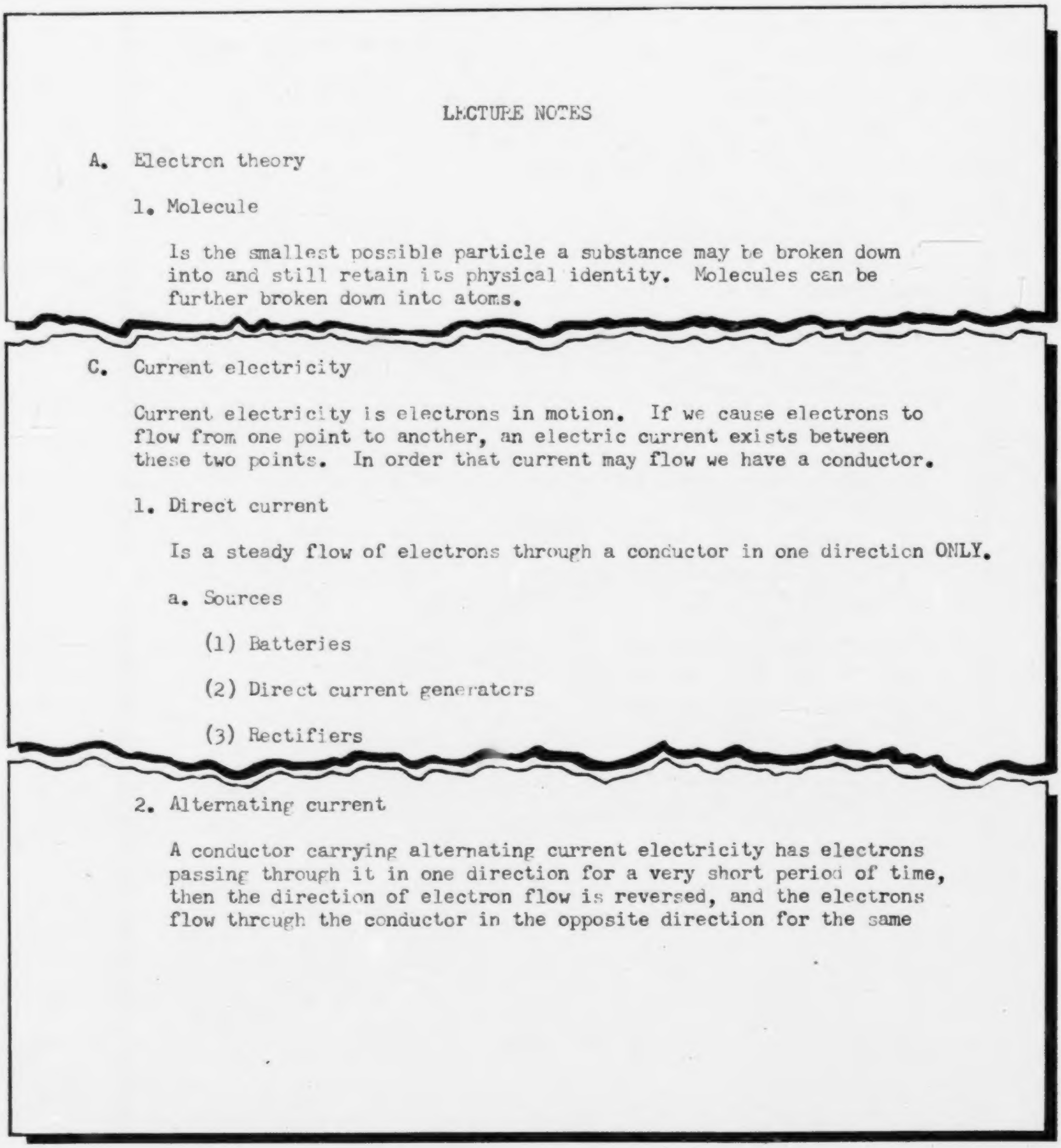
Describe here the means for determining the effectiveness of your instruction. A fairly reliable estimate of trainee understanding and achievement can be obtained by judicious oral questioning and by close observation throughout the lesson. Short oral, written or performance tests provide an additional check on trainee learning.

IX. ASSIGNMENT

For maximum learning, it is desirable to give trainees a work assignment for the next lesson. Be sure to include what, how, when, and why for every assignment that you make.

26.132

Figure 2-11.—Suggested lesson plan format.



LECTURE NOTES

A. Electron theory

1. Molecule

Is the smallest possible particle a substance may be broken down into and still retain its physical identity. Molecules can be further broken down into atoms.

C. Current electricity

Current electricity is electrons in motion. If we cause electrons to flow from one point to another, an electric current exists between these two points. In order that current may flow we have a conductor.

1. Direct current

Is a steady flow of electrons through a conductor in one direction ONLY.

a. Sources

(1) Batteries

(2) Direct current generators

(3) Rectifiers

2. Alternating current

A conductor carrying alternating current electricity has electrons passing through it in one direction for a very short period of time, then the direction of electron flow is reversed, and the electrons flow through the conductor in the opposite direction for the same

26.133

Figure 2-12.—Lecture notes that may be used to complement the lesson plan.

specific job, or jobs. Information sheets may be used to introduce general or related information. Figure 2-13 shows an information sheet on d-c series circuits.

Job sheets may be used after you have provided theory and have demonstrated how a skill type job is to be performed. Job sheets may be used in class as an integral part of the lesson, or they may be used in a self-study situation where the instructor is available for consultation and can make frequent checks. Job sheets, as such however, are not generally used to teach a man how to do a job. Rather they provide the trainee with a directed means of applying the knowledge he has gained. For example, job sheets may be prepared to check a man out in performing calibrations, adjustments, testing, and troubleshooting. Job sheets ought to include situations where the user makes mental decisions similar to those he will make while maintaining and/or troubleshooting his equipment. Figure 2-14 will give you an idea of the format and contents of a portion of a job sheet that might be used for training a man how to turn a piece of brass stock.

Instruction that is of a continuing nature requires that assignments be made. Assignments, of course, can be made orally and can be of a general nature, but more discipline and direction can be put into the learning process when frequent use is made of prepared assignment sheets. Assignment sheets are particularly helpful in self-study situations.

TRAINING EVALUATION

The final phase of any training program is the evaluation of progress in terms of the original objectives. Is the training program really doing what it was designed to do?

Evaluation may be either formal or informal in nature. Formal evaluation is carried out through a testing program to find out what knowledge the student has gained, or what level he has reached. Informal evaluation consists mainly of supervision and contact on a more personal plane: interviews, conferences, and inspections are used to determine whether teaching procedures and environment are conducive to the learning process. The supervisor must be able to recognize defects when he sees them, and he should know how to apply corrective measures and to motivate his instructors to the solution he proposes.

Shops do not differ from civilian schools in the need for effective evaluation of teaching and teachers. Remedial and motivational supervision by the Navy administrator can certainly be expected to result in a better quality of instruction.

Here is a good thing to keep in mind to ensure that your on the job training program is always working:

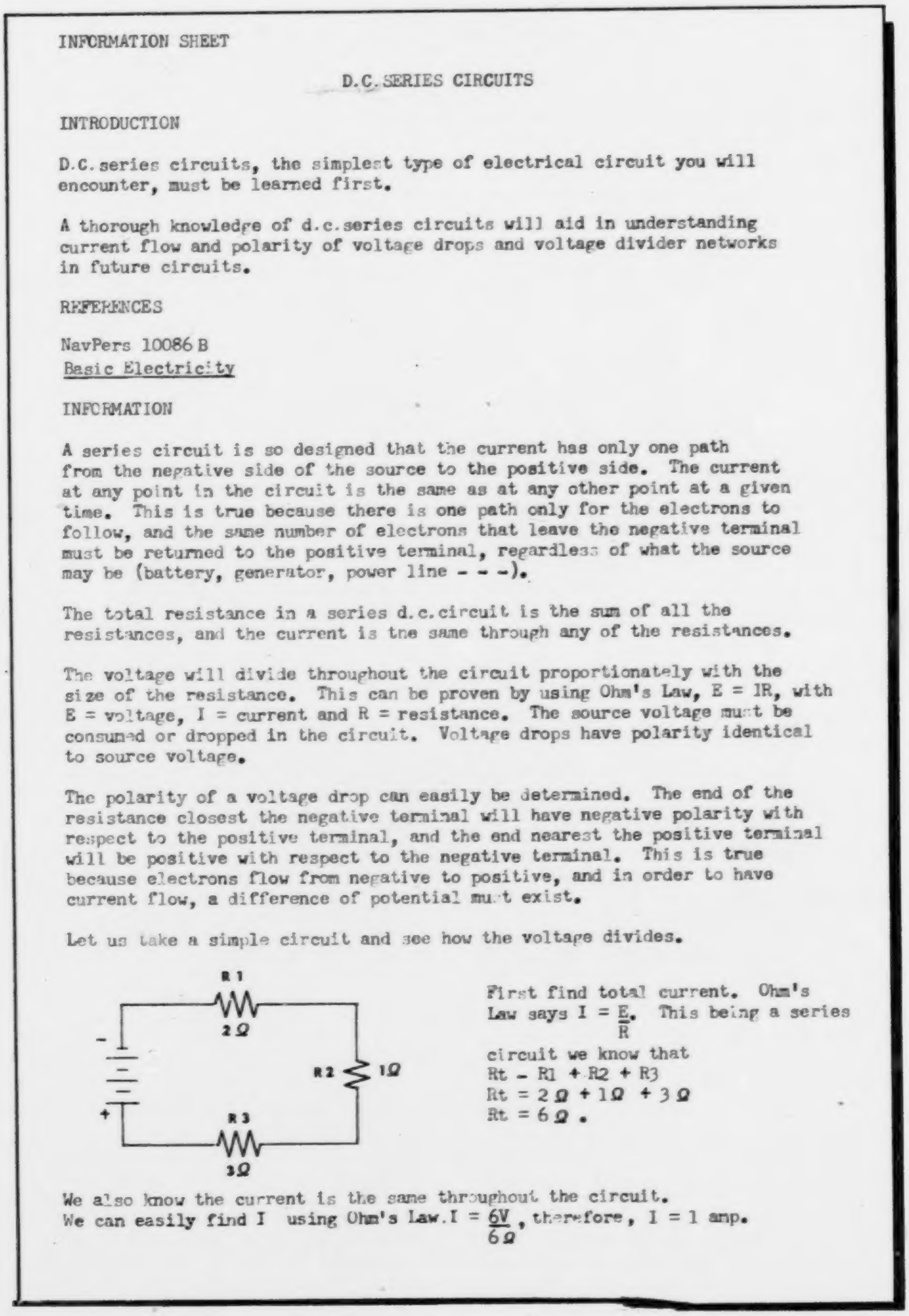
When you find yourself taking over work from another man, because he doesn't know how to do it right, or when a job comes into your shop that only you can do, it is time for on-the-job training. Try to be a valuable supervisor not an indispensible worker!

Motivation

Motivation may be defined as the effect of a group of incentives, physical, psychological, or social, which persuade an individual to a certain behavior. In the Naval situation, it may be assumed that physical needs are cared for. The social and psychological drives, therefore, are the one with which the training program must be most concerned.

The most efficient learning takes place when the student has a strong desire to achieve an actual and significant goal. His reasons for this desire may be many and varied. Future security, recognition, money, social or professional distinction are all factors which may motivate an individual to attain a goal. The late General Eisenhower is supposedly the author of the statement that "Leadership is the ability to get a person to do what you want him to do, when you want it done, in a way that you want it done, because he wants to do it."

The statement above probably epitomizes an additional excellent example or definition of motivation. Being able to direct your men so they want to achieve the same goals you do is the crux of your job. As you know, most men want to please their supervisors. Getting to know your men...learning as much as you can about them and their individual motivations will make your job easier and enable you to complete tasks within scheduled times more often. Your skill as an administrator will be enhanced as you can show each individual how his skills contribute to the central purpose of the group or project involved. Showing a man how the responsibilities he assumes contributes to the success of the desired goals of the group



INFORMATION SHEET

D.C. SERIES CIRCUITS

INTRODUCTION

D.C. series circuits, the simplest type of electrical circuit you will encounter, must be learned first.

A thorough knowledge of d.c. series circuits will aid in understanding current flow and polarity of voltage drops and voltage divider networks in future circuits.

REFERENCES

NavPers 10086 B
Basic Electricity

INFORMATION

A series circuit is so designed that the current has only one path from the negative side of the source to the positive side. The current at any point in the circuit is the same as at any other point at a given time. This is true because there is one path only for the electrons to follow, and the same number of electrons that leave the negative terminal must be returned to the positive terminal, regardless of what the source may be (battery, generator, power line - - -).

The total resistance in a series d.c. circuit is the sum of all the resistances, and the current is the same through any of the resistances.

The voltage will divide throughout the circuit proportionately with the size of the resistance. This can be proven by using Ohm's Law, E = IR, with E = voltage, I = current and R = resistance. The source voltage must be consumed or dropped in the circuit. Voltage drops have polarity identical to source voltage.

The polarity of a voltage drop can easily be determined. The end of the resistance closest the negative terminal will have negative polarity with respect to the positive terminal, and the end nearest the positive terminal will be positive with respect to the negative terminal. This is true because electrons flow from negative to positive, and in order to have current flow, a difference of potential must exist.

Let us take a simple circuit and see how the voltage divides.

First find total current. Ohm's Law says I = $\frac{E}{R}$. This being a series circuit we know that
Rt - R1 + R2 + R3
Rt = 2 Ω + 1 Ω + 3 Ω
Rt = 6 Ω .

We also know the current is the same throughout the circuit.
We can easily find I using Ohm's Law. I = $\frac{6V}{6\Omega}$, therefore, I = 1 amp.

26.134.1

Figure 2-13. — Information sheet.

TOPIC #3

JOB SHEET #3

Title: Turning a piece of brass stock

Reference: Bulova School of Watchmakers, Training Unit NO. 3
Pages 46 thru 48

Tools and Materials:

1. Lathe and bench
2. Brass stock
3. Hand Gravers
4. Tools in bench

Skills to be learned:

This assignment will give you practice in using the watchmakers lathe, hand gravers, micrometer and turning of small parts used in watches. At the end of this lesson you will have learned how to mount your stock in the lathe and turn it to certain specifications.

Procedure:

1. Select a number 30 chuck.
2. Select a brass rod three millimeters in diameter.
3. Chuck the brass rod in the lathe to extend out from the chuck fourteen millimeters.
4. Present the graver to the brass twelve millimeters from the end.
5. Start the turning by using the point of the graver until the rod has been turned off.
6. Remove the balance of the brass rod from the chuck.
7. Chuck the blank in the lathe so that the bevel plus one millimeter extends out from the chuck.
8. Use the left side and point of the graver to face off the blank.
9. Remove the blank from the chuck. Measure the length of the blank with the slide gauge and make a mark with the point of the graver 10 millimeters from the end that was faced off.
10. Chuck the blank in the lathe with the mark extending out from the chuck one millimeter.

91.421

Figure 2-14.—Job sheet.

usually makes him desire that responsibility rather than run from it.

Additional information for motivating your men as well as additional guidelines for conducting training are available in the training chapters of the current editions of Military Requirements for Petty Officers 3 and 2, and Military Requirements for Petty Officers 1 and C.

SECURITY

The Department of the Navy Security Manual for Classified Information, OpNav Instruction 5510.1C, provides a series of instructions and orders which establish a coordinated policy for the maintenance of the security of all information classified in the interests of national defense. A copy of it should be in the ship's office, or preferably, in your own shop.

You must become familiar with the contents of this book in such a way that you will be able to describe the elements of security found in the following chapters and articles.

Chapter 3: Security Orientation, Education and Training
All Articles

Chapter 4: Classification Management

Article 0405: Improper Classification
Article 0406: Misuse of Classification
Article 0423: Classification of Information according to Content
Article 0424: Dissemination Considerations
Article 0426: Specific Classifying Criteria
Article 0432: Individual Action
Article 0443: Regarding and Declassification

Read them. Study them. You will be asked questions about them on promotion examinations. One good way to learn these articles is to teach classes on security matters. Additional security material for which you are responsible is located in chapter 17 of Instrumentman 3 & 2, NavPers 10193-C.

CHAPTER 3

SAFETY

Safety is defined as security form danger, harm, loss, or injury. In the performance of your duties as an Instrumentman, you will direct installation, maintenance, and repair of equipment in which dangerously high voltages or explosive gases are frequently present. This work is often done in very limited spaces. Among the hazards of this work are electric shock, electrical fires, harmful gases which are sometimes generated by faulty electrical devices, and injuries which may be caused by the improper use of tools.

Because of these dangers, you should be aware that the formation of safe and intelligent work habits is fully as important as you knowledge of equipment. One of your primary objectives should be to train yourself and your men to recognize and correct dangerous conditions and to avoid unsafe acts.

SAFETY PROGRAM

It is the policy of the Secretary of the Navy to maintain an effective and aggressive safety program throughout the Department of the Navy for the purpose of preventing accidental deaths and injuries and material damages. An effective safety program includes the disemination of safety precautions which are known to be instrumental in preventing accidents and in maintaining a safe working environment.

The purpose of safety rules is to create within the individual an attitude of thinking and acting in terms of safety. Prescribed safety precautions are instrumental in avoiding preventable accidents and in maintaining a work environment which is conducive to good health. Operating procedures and work methods adopted with safety in mind avoid unnecessary injury or occupational health hazards. Accidents which are about to happen can be prevented if the "cause" is detected and appropriate remedial action is taken.

Study all safety precautions and their application to the particular installation with which you are concerned, and consider the possible need for specific precautions to guard against hazards peculiar to this installation.

RESPONSIBILITY FOR SAFETY

Although responsibility for the safety of personnel is vested in the commanding officer, he frequently delegates his authority to the executive officer and other subordinates to ensure that all prescribed safety precautions are understood and strictly enforced. The commanding officer requires that the personnel under his jurisdiction be instructed and drilled in applicable safety precautions; he requires that adequate warning signs be posted in dangerous areas; and he satisfies himself that such precautions are being observed. It is the responsibility of supervisory personnel to see that safety precautions are strictly adhered to in their own work areas, since they, in turn, are under orders from, and responsible to, the commanding officer. Furthermore, each individual concerned shall strictly observe all safety precautions applicable to his work or duty. Thus, it can be seen that safety is the business of every individual — not just a delegated few.

As an individual, you have a responsibility to yourself and to your shipmates. Always be alert to detect and report unsafe work practices and unsafe conditions so that they may be corrected before they cause accidents.

Human error includes all the actions or inactions of an individual having a bearing on an accident or an unsafe practice that can lead to an accident. To reduce human error as a predominant cause of accidents, it is the responsibility of every individual to acquaint himself with the surrounding environmental hazards. He should condition himself to be alert, both mentally and physically, so that he can protect himself and others by not foolishly or unnecessarily exposing himself to hazards.

SAFETY ENFORCEMENT

As a petty officer, you have the same responsibilities all other equally rated petty officers have in enforcing all safety precautions. These, as well as all rules and regulations, must be enforced. It is your duty to take appropriate action at any time you see a man disregarding a safety precaution. There is no room for prima donnas. You must require all jobs to be accomplished according to applicable safety procedures. Doing a job the safe way may take a little longer in some cases or be a little more inconvenient, but there is no doubt as to the importance of doing every job in this manner.

Remember—you can influence the behavior of your men by example, by developing safe working conditions and work procedures, and by teaching these procedures and insisting on adherence to them.

TEN COMMANDMENTS

Require your men to obey the ten commandments of safety:

1. LEARN the safe way to do your job before you start.
2. THINK safety, and ACT safety at all times.
3. OBEY safety rules and regulations—they are for your protection.
4. WEAR proper clothing and protective equipment.
5. CONDUCT yourself properly at all times—horseplay is prohibited.
6. OPERATE only the equipment you are authorized to use.
7. INSPECT tools and equipment for safe condition before starting work.
8. ADVISE your superior promptly of any unsafe condition or practice.
9. REPORT any injury immediately to your superior.
10. SUPPORT your safety program and take an active part in safety meetings.

"Safety Pays With Happy Days."

ELECTRICAL SAFETY

Make sure than all your men are aware of and are observing all safety precautions and expecially those regarding electrical safety. You can't expect a man to observe a precaution if he is unaware of the hazard. Therefore, your first duty will be to ensure that all of the men in your group are aware of the general safety precautions applicable to the base or ship. Then, ensure that all your men have read and understood all posted safety precautions relating to the electrical equipment on the base or ship.

The installation, maintenance, and operation of test equipment necessitates a stern safety code. Noncompliance with the code on the part of the Instrumentman can result in serious injury or death due to explosion, electrical shock, falls, burns, flying objects, and similar causes.

Accident investigations have revealed that the majority of accidents result from unsafe practices or acts, most of which are known beforehand to be unsafe and in violation of safety practices, rules, regulations, or directives.

Electricity must be treated with respect and handled properly. Stress this factor to your men over and over. If water exists anywhere in the vicinity of live equipment—be especially cautious, and whereever possible, deenergize the equipment.

Emphasize to the men the importance of learning the proper procedures when working on electrical equipment and to check to see that everything is in order before they turn any switches or energize any equipment or circuitry. If any doubt exists as to what the individual is doing, he is to check with another trained individual before proceeding any further. Always remember and teach your men that:

- Electricity strikes without warning.
- Hurrying reduces caution and invites accidents.
- Taking time to be careful saves time in the end.
- Taking chances is an invitation to trouble.
- Every electrical circuit is a potential source of danger and MUST BE TREATED AS SUCH.
- Even in cases of emergency, never work on an energized circuit. It must be considered that the circuit is energized until a personal check has been made to see that

the switch is opened and tagged, and the circuit has been tested with a voltmeter, or voltage tester.

REPLACING FUSES

Whenever practical, a circuit should be checked out before a burned-out fuse is replaced. The trouble is usually indicative of a circuit fault. Fuses are safety devices and should be used as such. A blown fuse should be replaced by a fuse of the same rated voltage and ampere capacity. Where removable fuse links are used, only one link of the correct rating is to be used for each fuse. Insertion of metal discs, coins, etc. in the back of plug fuses or the shorting out of cartridge fuses is strictly prohibited. NEVER SHORT OUT A FUSE.

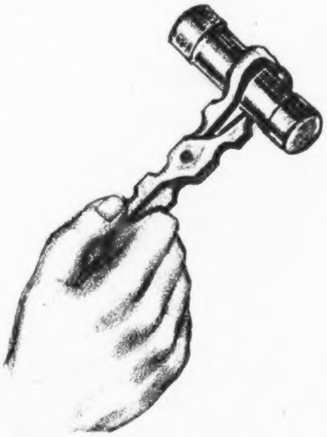
When it is necessary to remove a fuse, the operating switch should be opened to remove the load, and the fuse extracted with an insulated fuse puller (fig. 3-1) except where, as is usually the case on switchboards, the fuses are mounted in plug type fuse holders. These fuses are removed by unscrewing the plugs.

Only fuses of 10-ampere rated capacity or less should be removed from or replaced in energized circuits and only if an emergency exists.

Fuses larger than 10-ampere rated capacity should be removed or replaced only when the circuit is completely deenergized. After the replacement, the circuit should be energized only when the cover over the fuses is closed. Neglect of this precaution has led to injuries caused by explosion of a fuse when the circuit was energized.

DISCHARGING CAPACITORS

Before you touch a capacitor which is connected to a deenergized circuit, use the safety shorting probe to short-circuit the capacitor terminals and make certain that the capacitor is completely discharged. Also, before you handle a capacitor which is disconnected from the circuit, use the probe to short-circuit the capacitor terminals and to short-circuit each terminal to the capacitor case. (Never store a capacitor with a charge; always discharge the capacitor before storing it as a spare.)



1.32(91C)

Figure 3-1.—Using a fuse puller.

GROUNDING

Metal cases, bases, frames, and other metal parts of electrical equipment, appliances, machines, and fixtures powered from supply circuits in excess of 30 volts ac or dc, shall be grounded. Where inherent grounding is not provided by the mounting arrangements, ground connections shall be provided to ground the frame, enclosure, or support of permanently installed electrical equipment. Semiportable equipment which is normally used at fixed location shall also be grounded. Portable electrical equipment in conductive housings shall have adequate grounding.

Electrical and electronic workbenches must have a four-foot ground lead for every four feet of workbench.

The grounding conductor shall have a cross sectional area at least equal to, and preferably greater than, the cross sectional area of the line conductors which carry power to the equipment. The grounding conductor shall make positive metal-to-metal, low resistance contact with the equipment at one end and at the other end with the metal object used as a ground, the hull of the ship in shipboard installations, and the ground rods, water pipes or installed grounding object in shore installations. The resistance between the earth and the metal object used as ground shall not exceed 3 ohms ashore and 1 ohm aboard ship.

Never open ground connections at ground pipe or at ground bus bars unless they have been first disconnected at the point of contact with the equipment they are intended to ground.

This prevents an accident if the ground wire or bus bar should become energized.

INSULATING FLOOR COVERING

On all circuits where the voltage is in excess of 30 volts, the men shall be insulated from accidental grounding by use of approved insulating material on the floor at operating and working locations. The material shall have the following qualities:

It shall be dry, without holes, and shall not contain conducting materials. The voltage rating for which it is made shall be clearly marked on the material, and the proper material shall be used so that optimum protection from the voltage can be supplied.

On voltage below 600 volts, dry wood may be used, or, as an alternative, at least two layer of dry canvas, sheets of phenolic material, or rubber mats. Where other than approved rubber mats are used, the marking provision of the paragraph above shall not apply; however, care shall be taken to ensure that substitute material is capable of providing the required insulation value.

On circuits above 600 volts, nonconducting rubber matting of an approved type shall be used.

Care shall be exercised to ensure that moisture, dust, metal chips, etc., which may collect on insulating materials is removed at once. Small deposits of such materials can become hazardous.

EMERGENCY PROCEDURES

Artificial respiration and cardiac massage are emergency lifesaving techniques which you and your men should be able to apply. These techniques and certain power releases and time precautions are described in chapter 4 of Instrumentman 3&2, NAVPERS 10193-C. DO NOT try to administer first aid or come in physical contact with an electric shock victim before the voltage is cut off, or, if the voltage cannot be turned off immediately, before the victim has been removed from the live conductor.

SAFETY EDUCATION AND PROMOTION

As an Instrumentman First Class or Chief Instrumentman, you have a responsibility to provide electrical safety education to all Instrumentmen, particularly those whose primary duties are nonelectrical, regarding these precautions. The responsibilities in this area are ever increasing as more and more electrical machines and equipment are utilized for various jobs. Facts to be brought out and points to stress to the men should include:

- Information regarding electrical shock and precautions against it.
- Voltages as low as 30 volts can be and are dangerous.
- Make no electrical repairs.
- If there is any doubt, have the device tested by authorized electrical personnel.
- Always report any shock received from electrical equipment. Minor shocks may lead to fatal shocks.
- Before using any portable equipment, visually inspect it, looking for damaged or frayed cords.

Accidents do not happen without a cause; when each individual can be made safety minded and taught to think and act in terms of safety, fewer accidents will result. Safety must be a continuous effort in which each individual gains experience and knowledge through day-to-day association with coworkers who are safety conscious. Therefore, why not start your own personal safety program?

THINK SAFETY

TALK SAFETY

SELL SAFETY

Promoting safety within the Instrument group will require you to become safety conscious to the point that you automatically consider safety in every job or operation. By safety reminders and your personal example you will pass this safety consciousness on to the other men.

Usually one learns by experience. Learning safety by your own personal experiences would be foolish indeed since it is so unnecessary and dangerous. Most of the rules and regulations are based on someone else's experience. Instruct your men to follow these rules and regulations since most of them are based on common sense as well. Tell them to ask you if they don't understand the reasons for certain procedures—and to keep asking until you provide the ansers. Explain to your men that some men learned the rules—the hard way.

All men, even the old hands, need to be reminded occasionally to work safely. The list of senior rates involved in fatal accidents bears out this fact.

To jostle the men into the habit of safety consciousness, various methods for safety promotion can be used. Posters, such as figure 3-2, are furnished periodically to the fleet and overseas bases. These can be used as reminders for promoting safety. Post them in your work areas and change them when new ones become available.

Periodic safety patrols or inspections made by junior men in the group can also be helpful in reducing electrical hazards such as storage of foreign articles in or near switchboards and control panels. These may take place at any time and without prior preparation. Perhaps one of the men has received a slight shock. This can be the basis for the discussion. Possible fatal consequences under slightly different conditions will relate this pointedly to all personnel.

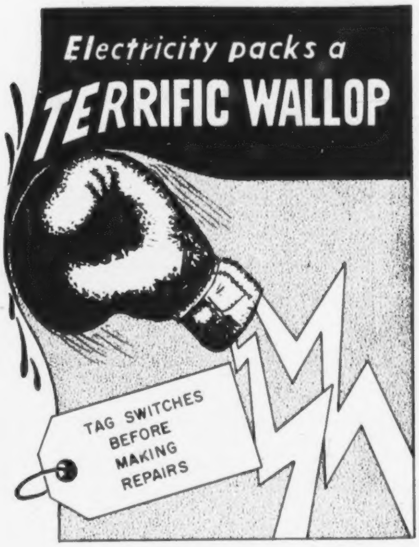


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Figure 3-2.—Safety poster.

SAFETY INFORMATION SOURCES

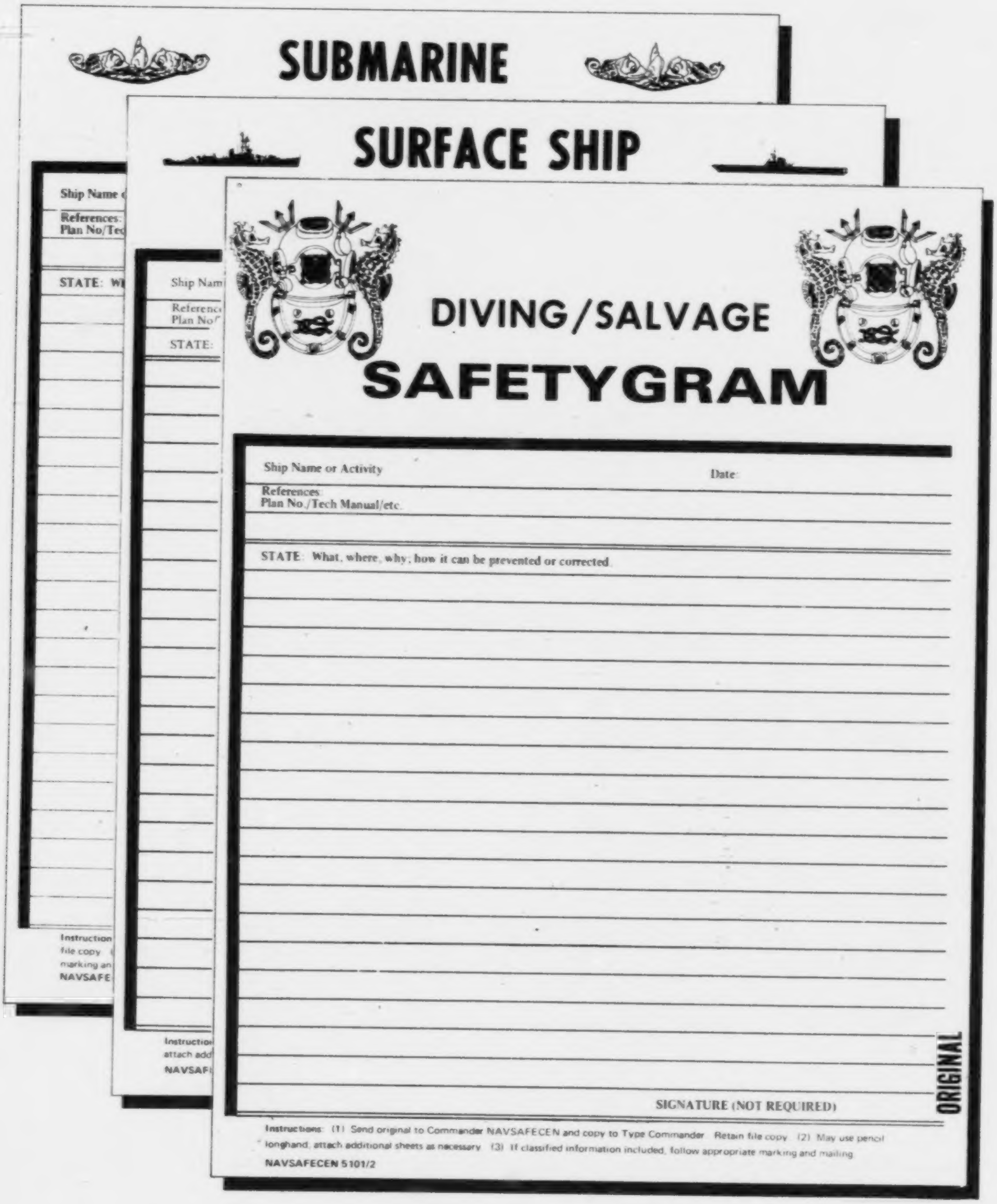
A variety of publications provide you with safety information. These include the Naval Ships Technical Manual, Naval Ship Systems Command Technical News, Naval Safety Center publications, and manufacturers' instruction manuals. In each of its chapters, the Naval Ships Technical Manual contains general safety rules or measures that are applicable to the main subject of the chapter. For example: Article 9870.82 cites safety measures to protect personnel from the connecting gears of counters; article 9230.31 cites general safety rules governing the use of compressed gas cylinders and gases. The Naval Ship Systems Command Technical News often publishes articles of interest to Instrumentmen, such as articles that discuss safety or provide up-to-date information on calibration programs.

Safety material is promulgated to the fleet on a continuing basis by the Naval Safety Center. The Submarine Directorate issues Submarine Safety Notes, Diving and Salvage Safety Notes, Maintenance/Material Safety Bulletins, Semiannual Casualty Analysis Reports and Miscellaneous Casualty Briefs. The Surface Ship Directorate issues the Ships Safety Bulletin monthly and has recently issued a second periodic report on forces afloat accident information. Submarine, Surface Ship and Diving/Salvage Safetygrams (fig. 3-3) provide an excellent means for fleet units or individuals to participate informally in the safety program. Both directorates collaborate in the publication of Fathom magazine, which has proven to be an effective method of getting safety information to the fleet (fig. 3-4). In addition, the safety Center makes available posters and other safety education material which can be beneficial to safety efforts and accident prevention programs throughout the fleet.

Finally, manufacturers' instruction manuals and rate training manuals are good sources of safety material. They describe the safety hazards of the equipment and material for which a man is responsible. Read them carefully and follow their instructions precisely.

SAFETY TALKS

When you deliver a safety talk, do you get yawns or action? If it's action, then your talks are producing the results that they should. But, if your safety messages aren't getting through, there are probably steps you can take to improve them. Here are five ways in which you



SUBMARINE

SURFACE SHIP

DIVING/SALVAGE

SAFETYGRAM

Ship Name or Activity Date:

References:
Plan No./Tech Manual/etc.

STATE: What, where, why; how it can be prevented or corrected.

SIGNATURE (NOT REQUIRED)

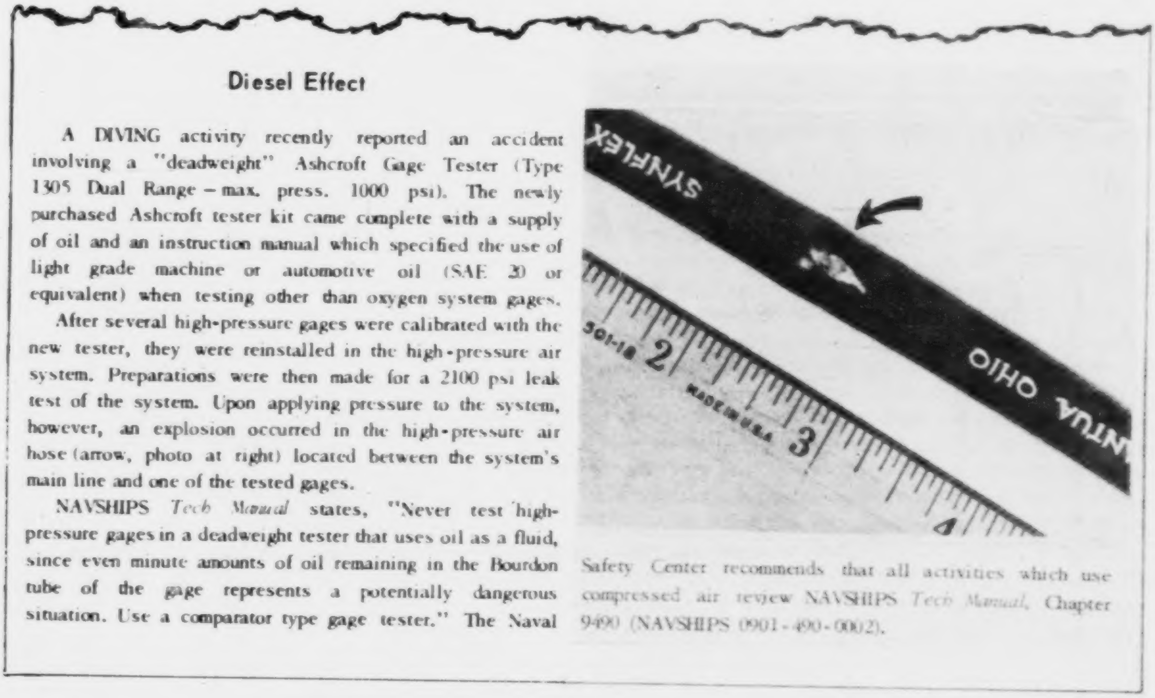
ORIGINAL

Instructions: (1) Send original to Commander NAVSAFECEN and copy to Type Commander. Retain file copy. (2) May use pencil longhand, attach additional sheets as necessary. (3) If classified information included, follow appropriate marking and mailing.

NAVSAFECEN 5101/2

91.551

Figure 3-3.—Safetygram forms.



Diesel Effect

A DIVING activity recently reported an accident involving a "deadweight" Ashcroft Gage Tester (Type 1305 Dual Range—max. press. 1000 psi). The newly purchased Ashcroft tester kit came complete with a supply of oil and an instruction manual which specified the use of light grade machine or automotive oil (SAE 20 or equivalent) when testing other than oxygen system gages.

After several high-pressure gages were calibrated with the new tester, they were reinstalled in the high-pressure air system. Preparations were then made for a 2100 psi leak test of the system. Upon applying pressure to the system, however, an explosion occurred in the high-pressure air hose (arrow, photo at right) located between the system's main line and one of the tested gages.

NAVSHIPS *Tech Manual* states, "Never test high-pressure gages in a deadweight tester that uses oil as a fluid, since even minute amounts of oil remaining in the Bourdon tube of the gage represents a potentially dangerous situation. Use a comparator type gage tester." The Naval Safety Center recommends that all activities which use compressed air review NAVSHIPS *Tech Manual*, Chapter 9490 (NAVSHIPS 0901-490-0002).

Figure 3-4.—Article from Fathom magazine. 91.552

can make sure you are driving home the principles of good safety habits.

Prepare

Even if you think you know safety forward and backward, don't wait until you're standing in front of your audience before you start thinking about what to say. What comes out will probably be rambling and disorganized. In preparing safety talks, there's plenty you can do in the course of your daily activities. For example, you can write down ideas, quotes, notes on safety incidents, and other observations you make during your work day. Carry a small notebook and you will soon build up a bank of reference material that you can draw on when you're preparing a safety talk.

Read all safety literature with your talks in mind. Whether it's a release from a safety organization, or an article from a newspaper, trade journal, or popular magazine, ask yourself, "What's in here that I can use?" If there is anything, jot it down, or clip out the entire article and file it. With a different folder for each aspect of safety, you can easily locate source material on the particular subject you want to talk about.

Get the know-how of others on safety. Others may have good ideas you can use in your safety talks. Listening to others talk about safety will often tip you off to the gaps in their knowledge that needs filling.

Organize your talk before you get up to make it. Prepare notes—it's especially useful to have facts and figures at your fingertips. Don't read your speech but use your notes to keep yourself on the track.

Pinpoint

Since you will usually have to keep your safety talk short, don't try to cover too much ground. It's more effective to concentrate on one limited subject and deal with that comprehensively. For example, you might discuss a specific safety rule, analyze a recent accident, or talk about fire prevention.

Personalize

A lot of dry, technical talk about safety won't leave much of a dent in your listener's minds. To give an effective safety talk, make it personal.

Present

Try to make it as easy as possible for your listeners to absorb your safety message.

The more graphically you present your talk, the more likely it is to be remembered. Once you have picked your subject, consider the visual aids you might use to drive home the points you wish to make. Demonstrations, movies, slides, displays, and charts can all contribute to the impact of your talk. For example, you can dramatize the importance of eye protection and the results of the loss of vision by using the "blindfold test." Several volunteers are blindfolded and then asked to light a cigarette, eat, write, and move around. The results of such exposure bring the message across very vividly.

Take the time to prepare your props so that there will be no interest-killing delays. If charts are used, they should be clear and easy to read, displayed as near to the audience as possible, and removed as soon as they have served their purpose.

Prescribe

Your purpose in giving a safety talk is not just to inform — it is also to get action. Let your audience know exactly what safety goal you are aiming for, and how they can contribute to its accomplishment. If possible, set a specific safety target and devise a method of graphically showing progress toward it.

Good safety talks don't just happen. They must be well presented and if you work at them by preparing, pinpointing, personalizing, presenting, and prescribing, they will work for you.

TRAINING TIPS

When it comes to training or retraining your men in safe practices, you may get discouraged with the slow progress you make with some of your men. But you should bear in mind that education is a slow process, adult education is even slower and adult re-education is slowest of all. A good part of safety instuction may consist of eradicating bad habits that men have acquired on previous jobs. And this is much tougher than trying to get a man to form a new habit. Here are some pointers that may make your safety training job easier:

Use words that mean the same to your subordinates as they do to you. Speak in short sentences and pause between sentences to give your subordinates time to absorb what you are saying.

Tell the man exactly what he is doing wrong. Are his motions incorrect? Is his timing wrong? Is he skipping some vital step? In your instruction, emphasize what to do rather than what not to do. As your men offer their own suggestions for making the shop a safer place to work in, let them participate when possible, in making decisions about safety practices and procedures. This will help them to become more safety-minded and will increase their adherence to safety rules.

Try to make safety regulations as specific as possible. General rules that apply in some cases and not in others may cause confusion. The majority of men like rules that spell out clearly what they should or should not do in certain situations.

TOOLS AND MACHINERY

As a supervisor, you must be safety conscious when observing, correcting, and training operators of tools and machinery. Neither you nor they can afford to treat safety with indifference. A disability check is poor compensation for the loss of an eye or a limb.

HANDTOOLS

Be sure that all tools conform to Navy standards of quality and type. Use each tool only for the purpose intended. All tools in active use should be maintained in good repair and all damaged or nonworking tools should be returned to the toolkeeper. Do not leave tools on floors, platforms, ladders, or on shelves above moving machinery. Keep tools and hands free of grease, and clearn tools with an approved solvent. Tools and other materials shall not be thrown or dropped down to personnel working on another level. They are to be raised or lowered by means of handlines or canvas toolbags or buckets. Men should stand clear when tools and other materials are bring raised or lowered.

Care must be taken when selecting pliers, side cutters, or diagonal cutters. Pliers or cutters should never be used on nuts or pipefittings. Teach your men to always hold the pliers or cutters so that the fingers are not wrapped around the handle in such a way that they can be pinched or jammed if the tool slips. When cutting short pieces, take care that parts of the work do not fly and cause injury.

Tools having plastic or wooden handles that are cracked, chipped, splintered, or broken may result in injuries to personnel from cuts, bruises, particles striking the eye, etc. Such tools should be condemned, replaced, or, if at all possible, repaired, before they cause accidents. NEVER PUT EXTENSIONS ON TOOL HANDLES TO INCREASE LEVERAGE.

When selecting a screwdriver for electrical work, be sure that it has a nonconducting handle. The screwdriver selected should be of the proper size to fit the screw and should never be used as a substitute for a punch or a chisel. The blades of screwdrivers can be kept in proper shape with a file or a grinding wheel.

Use wrenches only if they are right for the job and only if they are in good condition. An adjustable wrench should be faced so that the movable jaw is located forward in the direction in which the handle is to be turned.

Grease must be handled carefully and used only for the purpose intended. Serious injury has resulted when grease has been shot out of a grease gun in horseplay; NEVER point the gun toward another person.

PORTABLE POWER TOOLS

Make sure your men read carefully the operating instructions for tools, learning their applications, limitations, and potential hazards. Keep the tools sharp and clean for best and safest performance. Follow instructions for lubricating and for changing accessories, such as blades, bits, and cutters. Disconnect tools from their power source before servicing them or changing accessories.

An electric power tool equipped with a 3-prong plug must be connected to a 3-hole receptacle; the grounding prong is never removed. Ground all your electrical tools unless they are double insulated. Never carry a tool by its cord or yank the cord to disconnect the tool from a receptacle. Keep the cord away from heat sources, oil, and sharp edges. Don't carry a plugged-in tool with a finger on its switch. Also don't operate electric-powered tools in damp or wet locations.

Keep work areas well lighted and clean; cluttered benches invite accidents. Disconnect and store tools that are not in use. Keep visitors a safe distance from work areas.

Form a habit of checking to see that chuck keys and adjusting wrenches are removed from tools before they are turned on. Keep guards in place and in working order. Don't force a small tool or attachment to do the work of a heavy-duty tool; you will do better work safely with proper tools. Use clamps or a vise to hold your work. This is safer than using your hand, and frees both hands to operate the tool. Keep proper footing and balance at all times; don't overreach.

Wear proper working attire; jewelry, ties, and loose-fitting clothes get caught in moving parts. Use safety glasses or goggles when grinding or in danger of being struck by a flying object. Also wear a face mask if the work is dusty.

SHOP MACHINERY

In your work as an Instrumentman you may be required to use shop machinery such as a power grinder or a drill press. In addition to the general precautions on the use of tools, there are several other precautions which should be observed when you work with machinery or assign men to operate it. The more important ones are:

Never operate mechanical or powered equipment unless you are thoroughly familiar with its controls. When in doubt, consult the appropriate instruction or ask someone who knows.

Always make sure that everyone is clear before starting or operating mechanical equipment.

Never try to clear jammed machinery without first cutting off the source of power.

When hoisting heavy machinery (or equipment) by a chain fall, always keep everyone clear, and guide the hoist with lines attached to the equipment.

Never plug in portable electric machinery without ensuring that the power supply is the same as called for on the nameplate of the machine.

Drills must be straight, undamaged, and properly sharpened. Tighten the drill securely in the chuck using the key provided; never secure it with pliers or with a wrench. It is important that the drill be set straight and true in the chuck. The work should be firmly clamped and, if of metal, a center punch should be used to score the material before drilling is started.

Be sure that power cords do not come in contact with sharp objects. The cords should not be allowed to kink, nor should they be allowed to come in contact with oil, grease, hot surfaces, or chemicals. When cords are damaged, they should be replaced instead of being patched with tape.

OFFICE MACHINES

Sufficient attention is not always given to the dangers of low voltage electricity in offices. Among the more common electrical hazards found in offices are: (1) Office machines, lighting fixtures, and appliances not properly grounded, (2) Defective electric cords, lighting fixtures, appliances, and switches, (3) Unauthorized and improperly supervised electrical connections and repairs, and (4) Loose outlet plates which may result in short circuits and cause shocks through contact with them.

Before reparing office machines, be sure they are properly located and not in danger of falling while in use. Never clean, oil, or adjust electrical appliances when they are in operation. When cleaning appliances which are controlled by a switch on the machine, be sure the switch is turned off and the plug pulled. Protection should be provided against moving parts on addressograph, mimeograph, calculators, adding machines, and other types of power-driven machines.

Be sure that all electrical equipment is grounded.

WORK IN CONFINED SPACES

A closed compartment or poorly ventilated space is any space not well ventilated or that has been closed for an appreciable length of time, or is normally occupied or regularly used but has been vacated and sealed because of damage or other reason. Examples of such spaces are unventilated storerooms, blisters, double bottom tanks, cofferdams, pontoons, voids, idle furnaces, and cold boilers.

No person shall enter any closed compartment or poorly ventilated space in any naval unit unless and until a gas-free certificate has been issued by the safety engineer or his authorized representative to certify that the danger of poisoning or suffocation of personnel, or the danger of ignition or explosion of flammable gases has been eliminated or reduced to the lowest practical minimum.

In case of emergency, it may be necessary to send a man into a compartment or tank not certified as being gas-free or as containing sufficient oxygen. This man shall be equipped with an air line mask or an onygen rescue breathing apparatus. A line shall be securely fastened to him, the line being held by attendants outside who shall be prepared to haul him out, if necessary, and insure that this line does not become fouled. When the air line mask is used, the hose shall be attached to a source of air fit for breathing (Not to an oxygen cylinder), and a slight positive pressure shall be maintained in the hose and face piece.

GAS-FREE ENGINEER

The gas-free engineer is qualified by training and experience to analyze hazardous conditions, especially with respect to entry into closed compartments, and has been authorized to decide in specific instance which precautionary measures shall be taken to safeguard personnel. He in turn may train and authorize competent persons to make preliminary inspections, gas tests, etc. The gas-free engineer or his authorized representatives shall have authority to order men out of compartments or to suspend work whenever an unsafe condition is found to exist. However, he shall immediately notify the supervisor or other responsible authority of any such cessation of work and of the reasons therefor. He remains on the scene of operations until normal or safe conditions are restored. When dictated by urgent service requirements, the authority of the gas-free engineer may be relaxed as necessary but only with the approval of the supervisor. Under such circumstances, and if it is practical to do so, the gas-free engineer shall be consulted as to the safest practical alternatives, and his recommendations shall be followed insofar as the circumstances permit.

The gas-free engineer is responsible for posting, in a conspicuous location near the entrance to a closed compartment, a suitable label or tag describing the condition of the compartment. Every label, tag, or certificate issued by the gas-free engineer gives complete information regarding the compartment or space to which it applies, and the date and time it was issued. If it shows a SAFE designation, it shall also show the date and time after which the safe condition cannot be depended upon to exist and the safe notation will not be valid.

HOT WORK

Hot work is defined as work that involves welding flame cutting, the use of open-flame equipment, or any work involving heating metal to or above a red heat. Riveting and any cold work involving the probability of striking sparks shall be considered as hot work, except when, in the opinion of the gas-free tester, circumstances do not necessitate such a classification. The precautions applicable to hot work shall apply to all other sources of flames, sparks, or intense heat, such as lighted cigaretts, open flame or electric cooking apparatus, nonexplosive-proof lights, electric motors, etc.

No job involving hot work in the way of flammable or explosive materials shall be undertaken until the gas-free engineer or his authorized representative has (a) indicated which precautionary measures are appropriate to make the space safe and (b) certified that applicable directions have been complied with so that men can work in the area without danger of poisoning or suffocation, and that hot work can be undertaken without danger of fire or explosion.

SAFETY NOTATIONS

Your men are less likely to misunderstand or be confused by safety notations after learning their definitions, limitations, and applications. These notations should be printed on colored tags, as indicated below.

Not Safe For Men - Nor Safe For Hot Work (red tag)

Workmen are in danger of poisoning due to hydrocarbon or other gases in excess of the limits of toxicity, either present or likely to be evolved under prevailing conditions; or they are in danger of suffication due to a deficiency of oxygen; or in danger of fire or explosion in the presence of hot work because the surrounding spaces have not been protected as required, concentrations of flammable vapors are within the limits of flammability, residues are likely to evolve dangerous amounts of flammable gases or vapors under the conditions prevailing, or flammable or explosive materials are likely to be affected by the hot work.

Safe For Men - Not Safe For Hot Work (yellow tag)

Hydrocarbon or other gases in excess of the limits of toxicity are NOT present and are NOT likely to be evolved by the entry of workmen or by prevailing atmospheric conditions and the oxygen content of the air is sufficient for the workmen. Workmen, however, are in danger of fire or explosion in the presence of hot work because the surrounding spaces have not been protected as required, concentrations of flammable vapors are within the limits of flammability, residues are likely to evolve dangerous amounts of flammable gases or vapors under the conditions prevailing, or flammable or explosive materials are likely to be affected by the hot work.

Inerted - Not Safe For Men Inside - Safe For Men And Hot Work Outside (yellow tag)

A nonflammable (inert) gas has been introduced into the space and its concentration is such that the oxygen content in the space will NOT support combustion or life. Or adequate measures have been taken to isolate the space from occupied spaces and to insure that it will remain isolated until the inert gas is disposed of.

Safe For Men - Safe For Hot Work (green tag)

Toxic gases or vapors in excess of the limits of toxicity are NOT present and are NOT likely to be evolved under ANY WORKING CONDITION likely to prevail, and the oxygen content of the air is sufficient for workmen. Or flammable or explosive materials or vapors have been removed or adequately protected, and surrounding spaces have been protected as required.

AIR SAMPLING AND ANALYSIS

The air in tanks which have been empty for a long time and the air in other closed or poorly ventilated spaces shall be tested for the presence of toxic or flammable concentrations of hydrocarbon or other vapors and for sufficiency of oxygen. Air conditions shall be checked with the flame safety lamp and the combustible gas or carbon monoxide gas indicator, or by chemical analysis as frequently as circumstances appear to require. A check shall be made before men enter if work has been suspended overnight or for any similar period. Persons entering spaces for gas tests should be equipped with air-line masks and lifelines tended by reliable men outside. If one or ore of the tests show any positive indication of the presence of any flammable vapor, regardless of whether it is below, within, or above the explosive range, the space shall be gas-freed and cleaned by the applicable procedures.

There is satisfactory assurance of freedom from toxic concentration of flammable gases when (1) the space has been thoroughly ventilated (2) tests with the combustible-gas indicators (and with the carbon monoxide indicators when available) have given NO indication of the presence of combustible gases (if any gas is indicated by the instrument, even though below the flammability limit, it is probable that the concentration is above the toxicity limit) and (3) tests with the flame safety lamp have indicated no oxygen dificiency.

These conditions do not positively assure freedom from toxic concentrations of nonflammable gases, such as carbon dioxide and nitorgen, and of vapors. However, when the space has been thoroughly ventilated, and there is no oxygen deficiency as indicated by the flame safety lamp, workers in such atmospheres will receive warning of danger through such symptoms as labored breathing, excessive fatigue from slight exertion, dullness, etc., a considerable time before more serious reactions are experienced.

Flame Safety Lamp

In general, the flame safety lamp is used only to show whether or not there is enough oxygen to support life. The presence of other dangerous conditions, however, is indicated by the action of the flame, as follows:

- Flame dies out — Deficiency of oxygen (less than 16 percent).

- Flame goes out with slight "pop" — Explosive concentration of gas.

- Flame flares up then goes out — Rich concentration of exposive gas.

- Flame flares up brightly — Lean concentration of explosive gas.

Combustible Gas Indicators

The combustible gas indicators can detect all mixtures of air or oxygen with combustible gases or vapors from fuel oils, gasoline, alcohol, acetone, and of illuminating or fuel gas, hydrogen, and acetylene. They are sensitive in showing the presence of concentrations of these vapors or gases up to the lower explosive limit and give an accurate measurement of the percentage concentrations of the mixture if it is in or beyond the explosive range. They are NOT, however, sufficiently sensitive to measure accurately the small concentrations of flammable gases which can have an appreciably toxic effect when breathed for an extended period of time (8 hours or more), nor do they detect nonflammable gases which are toxic. If an accurate determination of the gas concentration is desired, chemical laboratory analyses of air samples are necessary. However, the safest procedure is to eliminate dangerous gases and vapors entirely, or to use air-line masks when working for extended periods in suspected atmospheres.

Carbon Monoxide Indicators

Though more sensitive in detecting carbon monoxide than a combustible gas indicator, the carbon monoxide indicator is limited to the detection of this gas only.

TOXIC GASES

Breathing of the vapors from petroleum products gives effects ranging from mild exhileration, through irritation of the eyes, severe headache and complete intoxication, to unconsciousness and death. The effects become more pronounced as the percentage of concentration and time of exposure are increased. An added danger associated with breathing these vapors is the danger of accidents resulting from the dizziness induced by small concentrations not otherwise harmful.

Carbon Monoxide

Carbon monoxide may be present in compartments painted with a lineseed oil base paint and sealed immediately thereafter.

Hydrogen Sulfide

Hydrogen sulfide and other toxic gases will be generated by mildewing or rotting foodstuffs or other organic matter, such as cloth, leather, and wood. Mildewing and rotting are accelerated when the space is warm and humid.

Carbon Dioxide

An excess of carbon dioxide (CO_2) is frequently found in refrigerator spaces even though the spaces are undamaged and the foodstuffs are perfectly edible. This is due to the lack of ventilation and the tendency of foods to absorb oxygen slowly and give off CO_2. The concentration is rarely high enough to be dangerous unless a man stays in the space longer than a few minutes at a time, in which case he is liable to be overcome and eventually suffocated.

Oxygen Deficiency

Oxygen deficiency can be caused by the rusting of metal which has been cleaned to bare metal and then sealed. The mildewing and rotting of organic material in closed compartments can also cause an oxygen deficiency.

SUSPECTED COMPARTMENTS

Every closed compartment or poorly ventilated space, and all tanks, shall be considered UNSAFE for hot work until the gas-free engineer has inspected the space and has indicated that adequate safety measures have been taken.

Each space that accumulates hydrocarbon or other gases and is in contact with a space in or on which repairs will be made (including spaces in contact at the corners or in contact with the top or bottom) shall be inerted. Classify and label "INERTED—Not Safe for Men Inside—Safe for Men and Hot Work Outside." In the case of a minor repair, only those contacting spaces need be inerted which, in the judgment of the gas-free engineer, may possibly be affected by the hot work (as when working on the boundary of a tank but very close to the bulkhead between it and another tank). Other contacting spaces need not be inerted for a minor repair. The possibility of regeneration of gas due to open pipes or other connections between clean and dirty tanks should be recognized and guarded against.

SAFETY PRECAUTIONS

Smoking must not be permitted in confined spaces or areas. Matches, cigarette lighters, open flames, flashlights, ordinary electric light, or any sparking electric apparatus are not allowed in suspected compartments or near open hatches, doors, etc leading to them. Portable lights used by cleaning parties must be of the steamtight globe type, with exposed metal parts being made of a nonsparking alloy or protected so as to prevent sparking. Suitable fire extinguishing apparatus must be provided in the vicinity of unsafe compartments or spaces.

WORLD'S BEST PROTECTIVE DEVICE

In setting forth these rules and regulations for safe practices, it is fully recognized that all possible hazardous conditions cannot be foreseen and covered by adequate precautionary measures. Mental alertness and careful procedures in handling equipment and performing work is required at all times by all men so that hazards may be detected and overcome before they lead to personnel injury, or damage to equipment. Remember

THE WORLD'S BEST

PROTECTIVE DEVICE

IS A CAREFUL INDIVIDUAL.

CHAPTER 4

MIRCS

The increased complexity of ship systems (especially weapons, propulsion, and navigation) has made it necessary to improve the quality and accuracy of measurements. Problems existed in measurements because the measurements of one activity did not agree with those of another activity even though identical items were being measured. In such cases, there was a tendency to "write off" the discrepancies as variations in the measuring instrument. But, in fact, most of any discrepancy was due to the lack of standardized measurements. It was for the purpose of standardizing instrument measurements that the Navy Calibration Program was established. This program emphasizes the need for complete measurement standardization throughout the Navy. Ships and activities (which in the past have ignored this need because of economic considerations) must be able to see the program's technical and economic advantages. The program also sets up Mechanical Instrument Repair and Calibration Shops (MIRCS) to ensure continued accuracy within design specifications of measuring equipment, thus ensuring greater reliability in everyday use.

This chapter describes the structure of the Navy Calibration Program and points out the purpose, organization, components, and arrangements of MIRCS. Some of the descriptions given here are in general terms since shipboard equipment does vary from ship to ship, in spite of efforts to use standard equipment, techniques, procedures, and policies.

NAVY CALIBRATION PROGRAM

The Navy Calibration Program is a program of standardization of equipment and instruments used in making measurements, and the methods and techniques used in conducting these measurements. The function of the calibration program is to ensure the maintenance of accuracy within designed limits of all testing and measuring systems employed in the Navy. The calibration program provides for periodic calibration of standards and test equipment.

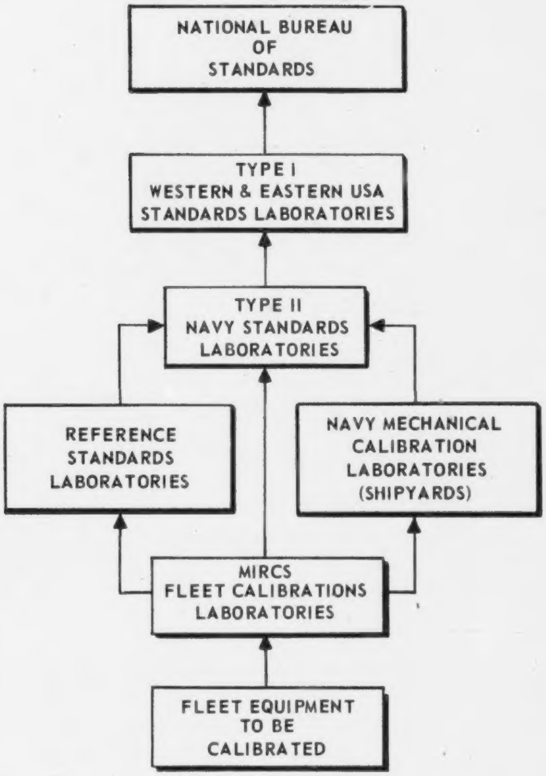
The Chief of Naval Material is the head of the Navy Calibration Program. Under the Chief of Naval Material each systems command (ordnance, air, ships, and electronics) controls and directs the use of standards and standard calibration facilities under its control. The Metrology Engineering Center (MEC) provides the scientific and technical support for the Navy Calibration Program.

TRACEABILITY OF STANDARDS

The U.S. Department of Commerce, National Bureau of Standards (NBS) (fig. 4-1), located at Gaithersburg, Md, is the focal point in the Federal Government for maintaining and advancing standards and technology for the physical and engineering sciences. NBS provides the common reference for Navy scientific measurements and certifies the standards used by the Navy Type I Standards Laboratories.

The Type I Standards Laboratories consist of two primary standards laboratories which provide services within the Navy Calibration Program. They are the Western Primary Standards Laboratory located at North Island Naval Air Station, Coronado, California and the Eastern Primary Standards Laboratory located in Washington, D.C. The Type I Standards Laboratories maintain and disseminate the most accurate units of measurements within the Navy Calibration Program. Type I laboratories (a) obtain calibration services from NBS and (b) provide calibration services to Type II and lower echelon calibration laboratories. The Type II laboratories are designed to furnish calibration services to lower echelon laboratories.

Navy Calibration Laboratories (shore), Fleet Mechanical Calibration Laboratories (FMCL),


NATIONAL BUREAU OF STANDARDS
TYPE I WESTERN & EASTERN USA STANDARDS LABORATORIES
TYPE II NAVY STANDARDS LABORATORIES
REFERENCE STANDARDS LABORATORIES
NAVY MECHANICAL CALIBRATION LABORATORIES (SHIPYARDS)
MIRCS FLEET CALIBRATIONS LABORATORIES
FLEET EQUIPMENT TO BE CALIBRATED

170.49(91C)

Figure 4-1.—Fleet equipment accuracy traceability chart.

and MIRCS comprise the next echelon of calibration services for fleet and shore units.

Figure 4-2 is a typical list of Type I, II, and shore calibration laboratories that furnish calibration services to MIRCS.

Fleet Mechanical Calibration Laboratories

FMCLs are installed on submarine tenders which provide services to Fleet Ballistic Missile (FBM) submarines. The primary difference between FMCLs and MIRCS is that FMCLs have dimensional and optical capabilities that are not available in MIRCS.

The FMCLs on the FBM tenders are operated by IM or OM personnel with (NEC) IM-1821, Mechanical Standard Specialist. Upon transfer to a FBM tender, the Instrumentman or Opticalman should acquaint himself with the (shipboard) Tender Calibration Instructions, and the FBM Calibration Program Information Manual, OD 30354. The Tender Calibration Instructions are written so as to establish firm guidelines for calibration laboratories and supporting shops. The FBM Calibration Program Information Manual provides the necessary information for the operation of a FMCL within the Navy Calibration Program.

STANDARDIZATION

Calibration by definition is the process of comparing the readings of a test instrument against a known standard. One of the basic problems in calibration is to define "a known standard" and ensuring that the "known standard" of one activity is identical to the "known standard" of another activity. This standardization of calibration is one of the prime objectives of the calibration program.

Standardization is basically achieved in two ways: standardization of equipment and standardization of procedures used to perform the calibration.

Equipment Standardization

Equipment standardization is accomplished by comparing the standards of all activities to a common standard. The following example demonstrates how this is accomplished:

Deadweight testers used to calibrate shop standard gages require calibration every three years. When due for calibration, they are taken to the support laboratory (type II or type I) where they are calibrated against the standards of that support laboratory. The support laboratory standards are traceable to a single standard at NBS. This standardization of equipment through traceability to a common standard ensures that all activities are performing identically.

Procedural Standardization

In order to ensure that calibrations performed by two different activities are identical, the method used to perform the calibrations must be the same for all activities. The method used to calibrate a piece of equipment includes such

CODE	LAB	LOCATION	CODE	LAB	LOCATION
EPP	I	ESL WASHINGTON, D.C.	SDP	I	WSL NAS NO. ISLAND
NRA	II	C.T.O. NEWPORT	ACP	II	NAS ALAMEDA
NAB	II	NAS NORFOLK	OHA	II	NAD OAHU
CHB	CAL	NWA CHARLESTON	WPP	II	BUWEPSREP POMONA
JFB	CAL	NAS JACKSONVILLE	ACL	CAL	NAS ALAMEDA
NXL	CAL	NAS NORFOLK	AGL	CAL	NAS AGANA
QPB	CAL	NAS QUONSETT POINT	AKL	CAL	NAS ATSUGI (COMFAIR WESPAC)
RAL	CAL	ROTA SPAIN	CPL	CAL	NAS CUBI POINT
YVA	CAL	NMEF YORKTOWN	SDB	CAL	NAS NORTH ISLAND

91.553

Figure 4-2.—Type I, II, and calibration laboratories.

things as what standard to use, how to use it, under what conditions, number of test points, etc.

The Metrology Engineering Center (MEC), Pomona has the responsibility of procedural standardization within the calibration program. These procedures are then the standard method of performing a calibration.

Instrument Standardization

Standards and measuring instruments must be calibrated often enough to ensure that they have not drifted beyond prescribed limits. When instruments are not calibrated often enough, errors may be produced. These errors, if undetected, may give a false impression that measurement standardization does exist. A CALIBRATION PERIOD must be established for each item. A calibration period or cycle is the designated length of time between calibrations of a particular piece of equipment. Such periods have been designated for all standards, associated instruments, and commercial measuring equipment within the Navy Calibration Program. New equipment is provided interim calibration periods until such time as a review of calibration data proves the need for changing these periods.

Selection of Standards

Normally, the standard to be used is specified in the calibration procedure. Studies were made to determine which selection factors are most important to the proper operation of measurement systems. Brief technical details of proper instrument selection and operation are as follows.

ACCURACY RATIOS.—It must be determined what accuracy is required for an intended measurement. It is desirable that measuring systems in calibration or testing work be 10 times (10-to-1 ratio) as accurate as the tolerances or test specifications of the systems being measured. For example, if a test is to be made on a piece of equipment which has an accuracy of ±20%, the measuring system accuracy should be within ±2%. Many limitations make it difficult to maintain a 10-to-1 accuracy ratio. Studies have shown that the lowest allowable accuracy ratio for most measurements in the calibration program is 4 to 1. This ratio provides measurements which are in error less than 3% of the time. In contrast, a 10-to-1 ratio yields measurements which are in error only 0.8% of the time.

After the measurement accuracy requirements are determined, a measurement system must be selected which meets the requirements. Emphasis is placed on measurement system accuracy rather than on instrument accuracy.

Errors produced by temperature, humidity, gravity, atmospheric pressure, and auxiliary equipment may be overlooked in favor of the error of the standard or prime indicating instrument. In many cases, the errors contributed by environmental conditions or auxiliary equipment far exceed that of the indicating instrument. Total system error is the sum of all the errors of the parts that make up the system which contribute directly to the measurement. The selection of a system of determining measurement system errors should be consistent with the requirement for measurement accuracy so realistic ratios can occur.

The accuracy value of each instrument or item of equipment should be applied carefully. Every instrument manufacturer normally states the rated accuracy of his equipment. The fine print should be considered before accepting an accuracy rating at face value.

There is a tendency to overlook the fixed value error of equipments whose accuracy ratings are given; for example, ±1% or ±1 scale division. At measurements on the low end of the scale, the error contributed by the ±1 scale division far exceeds the 1% accuracy figure. Again, the fine print needs to be read and thoroughly understood before equipment can be used for measurement.

Measurement problems and errors arise because of other frequently overlooked influencing factors, such as the following:

1. Failure to account for errors introduced by dynamic rather than static conditions
2. Failure to consider proper instrument placement where head effects, hose length, etc, are critical
3. Failure to consider environmental effects
4. Failure to consider loading effects
5. Failure to consider the human engineering aspects of instrumentation, such as the selection of equipment whose complexities exceed the skill of intended operators.

CALIBRATION OF MIRCS STANDARDS

Various means are used by MIRCS in funding, recalling, and contacting for calibration support.

In order to receive calibration support for standards, it is necessary to (a) request funds from the Type Commander, (b) request by official message calibration services from the supporting laboratory for standards needing recalibration, and (c) make up a recalibration schedule (recall) with the help of the supporting laboratory, so as to minimize the delay in getting your standards recalibrated and back in service.

A typical list of those shop standards that require shore support calibration are shown in figure 4-3. Not all working standards used in MIRCS require shore support calibration. Using the particular shop standard required for the instrument being calibrated, MIRCS personnel calibrate the working standard. For example, using the water, oil, or bifluid deadweight tester to calibrate gages in the low pressure and/or hydraulic panels.

CALIBRATION SERVICING LABELS AND TAGS

Standards require a sticker or equivalent certification, which shows the date and place of calibration, before they can be used to check operating instruments. Instruments calibrated by MIRCS require labels and tags as necessary to indicate the status of calibration or testing. In marking labels and tags, MIRCS personnel should insert in the DATE and DUE columns the appropriate month, day, and year, such as Dec 8, 1972. The Metrology Engineering Center's 3-letter code designation of the servicing MIRCS is written or stamped on applicable labels and tags. The various labels and tags for calibration standards or test and measuring equipment within MIRCS are shown in figures 4-4A and 4-4B.

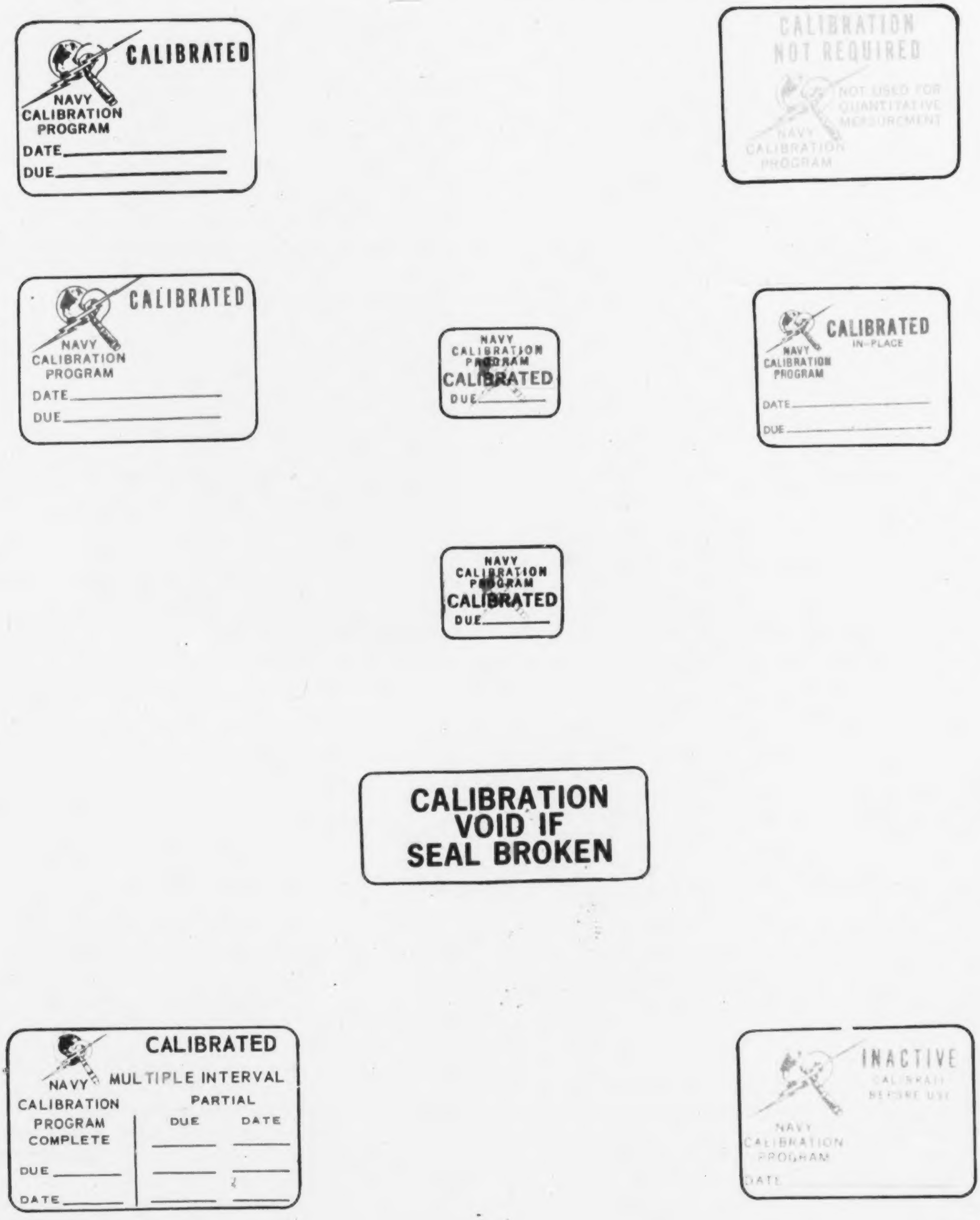
Calibrated

The CALIBRATED label is placed on each standard or test and measuring equipment that has been checked against a standard of higher accuracy, using approved Navy calibration procedures and checklists, and adjusted to meet (1) a predetermined specification (manufacturer's tolerance, or other) or (2) a specified value of magnitude and uncertainty. This specified value may be expressed for single-value instruments, such as standard cells, or for multivalue instruments, such as potentiometers. When an instrument is calibrated to meet a predetermined specification, only the knowledge that the instrument is within this specification is significant, and a black on white label is used. When an instrument is calibrated to meet an expressed value of magnitude and uncertainty, the actual measured value and associated uncertainty are

DESCRIPTION	CALIBRATION CYCLE (Months)	CALIBRATION FACILITY
Millivolt Box (Potentiometer)	12	Navy Cal. Fac.
Temperature Bridge	12	Navy Cal. Fac.
DC Resistance Box	12	Navy Cal. Fac.
Platinum Resistance Thermometer	6	Navy Cal. Fac.
Copper Resistance Thermometer	6	Navy Cal. Fac.
Glass Thermometer Set ASTM Precision (thermometers 62 to 70 F)	36	Navy Stds. Lab. Type II
Dead Weight Tester (Oil)	36	Navy Cal. Fac.
Dead Weight Tester (Bi-fluid)	36	Navy Cal. Fac.
Dead Weight Tester (Water)	36	Navy Cal. Fac.
Tachometer Calibrator	36	Navy Cal. Fac.
Vacuum Gage 1 to 100 microns HG	18	Navy Cal. Fac.
Glass Thermometer Set ASTM Precision (thermometers 62 to 70 C)	36	Navy Stds. Lab. Type II
Torque Wrench Testers (ALL)	6	Navy Cal. Fac.
Dead Weight Tester (Pneumatic)	36	Navy Cal. Fac.
Aneroid Barometer	18	Navy Cal. Fac.

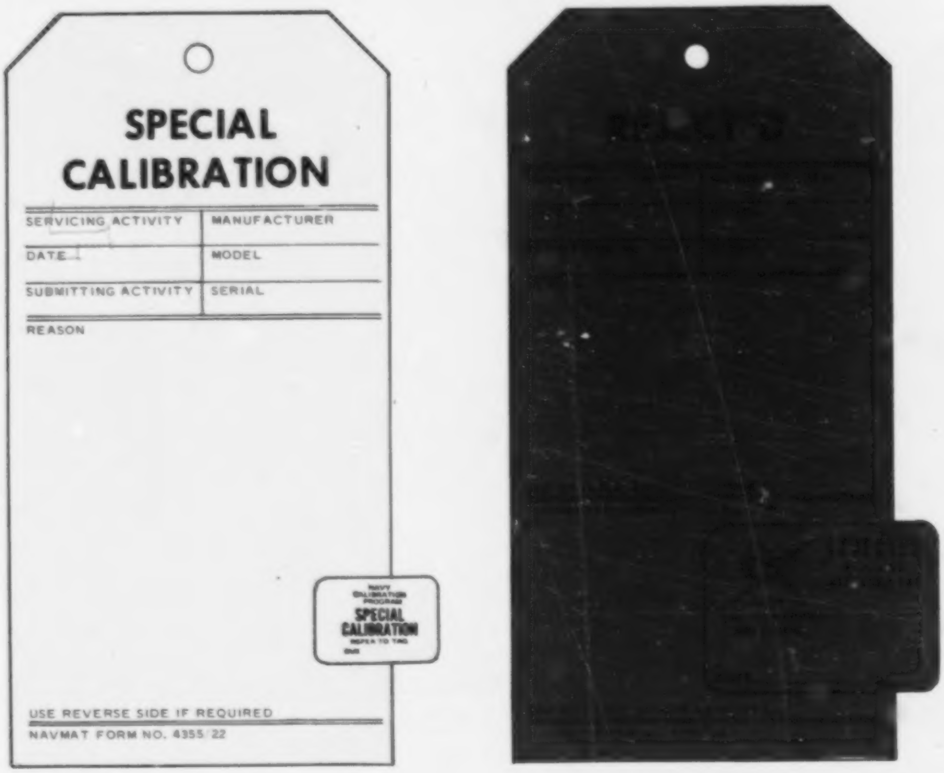
91.554

Figure 4-3.—MIRCS test equipment requiring shore support for follow up calibration.


CALIBRATED
NAVY
CALIBRATION
PROGRAM
DATE
DUE
CALIBRATION
NOT REQUIRED
NOT USED FOR
QUANTITATIVE
MEASUREMENT
NAVY
CALIBRATION
PROGRAM
CALIBRATED
NAVY
CALIBRATION
PROGRAM
DATE
DUE
NAVY
CALIBRATION
PROGRAM
CALIBRATED
DUE
CALIBRATED
IN-PLACE
NAVY
CALIBRATION
PROGRAM
DATE
DUE
NAVY
CALIBRATION
PROGRAM
CALIBRATED
DUE
CALIBRATION
VOID IF
SEAL BROKEN
CALIBRATED
NAVY
MULTIPLE INTERVAL
CALIBRATION
PROGRAM
COMPLETE
PARTIAL
DUE
DATE
DUE
DATE
INACTIVE
CALIBRATE
BEFORE USE
NAVY
CALIBRATION
PROGRAM
DATE

173.6

Figure 4-4A. — Labels.


SPECIAL CALIBRATION
SERVICING ACTIVITY
MANUFACTURER
DATE
MODEL
SUBMITTING ACTIVITY
SERIAL
REASON
NAVY CALIBRATION PROGRAM
SPECIAL CALIBRATION
REFER TO TAG
USE REVERSE SIDE IF REQUIRED
NAVMAT FORM NO. 4355/22

173.6

Figure 4-4B. — Labels and Tags.

reported, a red on white label is used, and a Report of Calibration is provided with the instrument.

Special Calibration

On occasion, specific user requirements do not involve the full instrument capability. In such instances a calibration is not performed over the entire range of the instrument. Only the needed quantities and ranges are calibrated. A SPECIAL CALIBRATION label (black and yellow) is used to draw attention to the special conditions under which the instrument is calibrated. In addition to the label, a special calibration tag is attached to the instrument. This tag is filled in by the servicing activity to adequately describe the conditions which are to be observed in the use of the instrument. The label and tag remain on the instrument until the next calibration. (They replace the former Limited Use label and tag.)

The 3-inch by 2-inch special calibration label may be used alone in lieu of the label and tag combination when space is available on the instrument and reasons for special calibration can be shown on the label itself.

Calibration Not Required -
Not Used for Quantitative Measurement

Some instruments normally fall within the category of equipment requiring calibration, but are not used for quantitative measurements for various reasons. With several like instruments, for example, only one or two are calibrated and used for quantitative measurements; the others are used as indicators only. Also, some instruments do not require calibration because they receive an operational check each time they are used, or malfunctions and/or loss of accuracy are readily apparent during their normal use. These instruments comprise components, such as amplifiers, junction boxes, line transformers and line regulators. A label (orange on white) indicating that calibration is not required because the instrument is not used for quantitative measurements is placed on the instrument.

Calibrated-Multiple Interval

Some instruments comprise components that require different calibration intervals. For example, the frequency section of a signal generator requires calibration every four months whereas the attenuator requires calibration every twelve months. In such cases, calibration man-hours can be saved by the use of the Calibrated-Multiple Interval label (black on white).

Calibrated-In-Place

The CALIBRATED-IN-PLACE label is used by on-site calibration teams to identify items, such as liquidometer indicators, that are calibrated in place and should not be forwarded to the calibration laboratory. These labels (blue on white) alert the ships' forces that the items should not be off-loaded when ships come into port.

Calibration Void If Seal Broken

This label (black on white) is used to prevent tampering with certain adjustments which would affect the calibration.

Rejected

If an instrument fails to meet the acceptance criteria during calibration and cannot be adequately serviced, a REJECTED label (black on red) is placed on the instrument and all other servicing labels are removed. In addition to the REJECTED label, a REJECTED tag is placed on the instrument. The tag is filled in by the servicing activity giving the reason for rejection and other information as required. The rejected label and tag remain on the instrument until it is repaired and reserviced. The instrument is not to be used while bearing a rejected label.

Inactive

The INACTIVE label is placed on an instrument of the type which normally requires calibration and is found to have no foreseeable usage requirements. The inactive label remains on the instrument until it is reserviced. The instrument is not to be used while bearing the inactive label.

MIRCS LABELS

Labels printed or procured locally are to be used on gages, tachometers, and other normal work instruments, such as the ones used on engines, boilers, and systems not used to test or calibrate other instruments. The labels may be printed using the MIRCS three letter code, with date, and date due, as shown in figure 4-5.

PREPARATION FOR SHIPMENT

Before standards are shipped to a higher echelon calibration facility, MIRCS personnel are to ensure that standards are clean and in good operating order. Deadweight tester pumps are to be cleaned, seals replaced, and pumps refilled with clean fluid. Equipment and standards that need repair are to be repaired by a local shop or returned to manufacturer before being sent out for calibration. Operation and technical manuals for the equipment are to be sent with the equipment when requested by the receiving facility. It is the Instrumentman's responsibility to see that operation and technical manuals are on hand for each item within MIRCS.

Packing and Shipping

All instruments and equipment to be shipped must be properly packed and suitably protected in accordance with the degree of protection required. Generally, the packing is done by the Supply Department for your activity.

The packing must provide suitable protection against mechanical shock and vibration, heat, moisture, breakage and must be appropriate for the type of transportation involved. All

VUR
date ________
due

91.557
Figure 4-5. — MIRCS label USS Vulcan (AR-5).

containers are marked FRAGILE, GLASS, HANDLE WITH CARE, etc, in accordance with MIL-STD-129a (latest revision), Marking for Shipment.

You must furnish the Supply Department with a complete list of the contents of the box and retain a copy of the list for shop records. The list should include manufacturer, model number, serial number, a description of the services desired, and special instructions, if any.

Methods of Shipment

In order of increasing severity of environmental effects, the available methods of shipment are:

1. Hand carrying
2. Air express
3. Air freight
4. Truck
5. Railway express
6. Railway freight

These methods are used by the Supply Department in shipping instruments and other material. Hand carrying is the only method of shipment that directly involves MIRCS personnel.

Hand carrying implies that the instrument will be literally held by a person throughout the trip in which case, most of or all the packing is omitted. But if the instrument is placed in a truck or on the floor or seat of an automobile or other conveyance, it should be packed to provide suitable protection.

CALIBRATION CHECKLIST

Calibration checklists are used in all calibrations performed by the laboratories participating in the calibration program. A checklist accompanies each MIRCS standard that is received from a higher echelon laboratory. Each working standard calibrated by MIRCS personnel has a properly filled out calibration checklist that provides for the recording of all information used in calibration of the standard. The checklist is filled out by the person performing the calibration. He should refer to the current instructions for his shop in filling out the calibration checklist. Figure 4-6 is a sample calibration checklist.

WORKCENTER LOCATION AND ARRANGEMENT

MIRCS workcenters vary as to location, size, and arrangement, depending upon which type of ship the workcenter is installed. Figure 4-7 is a diagram of a typical MIRCS on a repair ship (AR).

OFFICE AND WORK CONTROL AREA

This area should be one of the main concerns of the Chief or First Class in charge of MIRCS. It provides the space for filing, cataloging, and storing the many procedures, publications, Technical Manuals, forms, records, and reports needed by a smooth operating workcenter.

TOOL ISSUE AREA

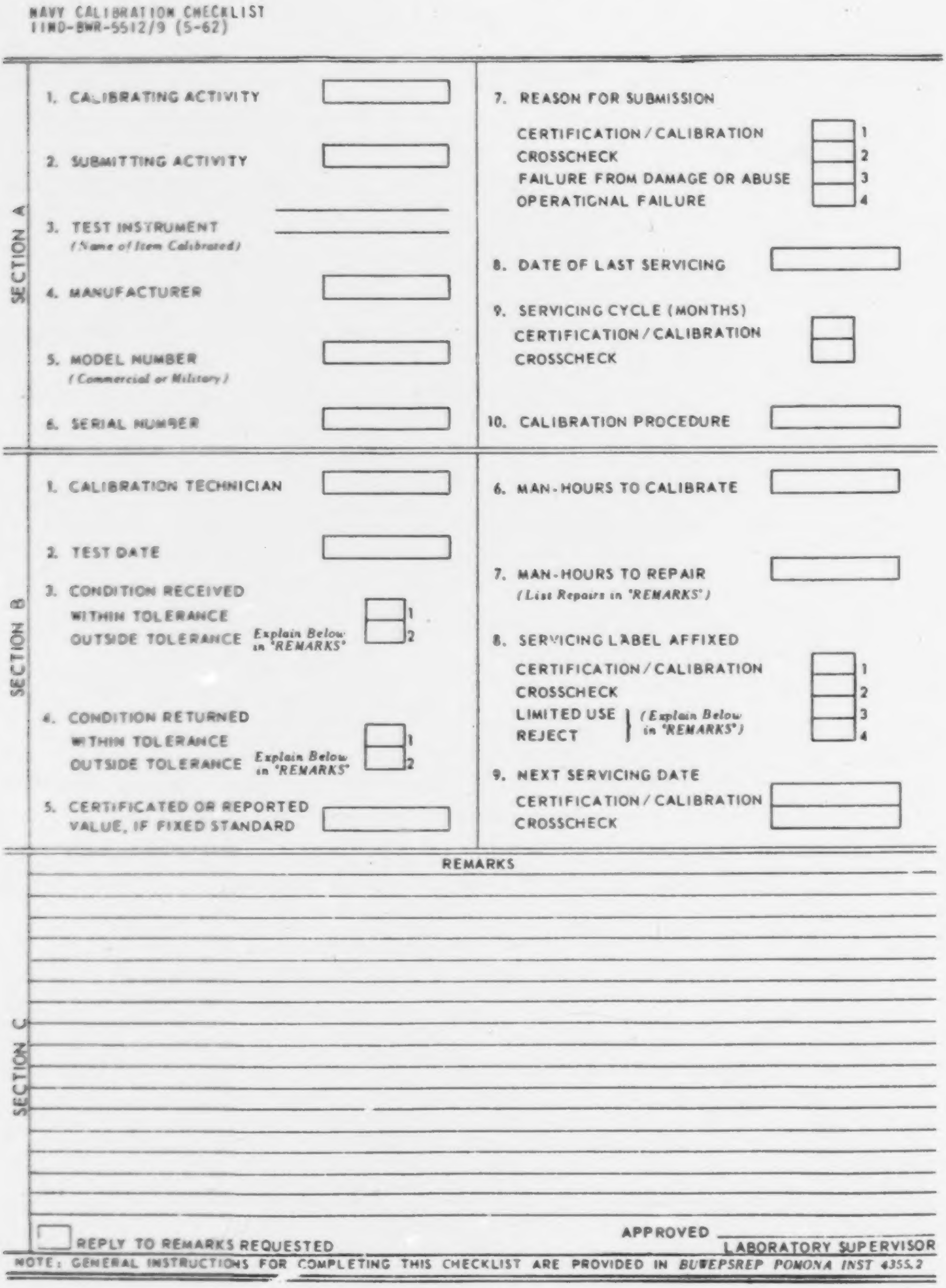
The tool issue area may be a separate tool issue room or be made up of centrally located lockers from which tools are issued. All tools in the workcenter should be cataloged, with location, amount, and to whom issued. The Chief or First Class in charge is accountable for these tools. He holds inventory periodically, and when relieving or being relieved of duty as the man in charge. Also, he keeps accurate records to account for all tools.

CLEANING AND REPAIR AREA

Two general cleaning areas are located in the shop: the gage cleaning area and the general repair area (fig. 4-7). The gage cleaning area has an assortment of evaporating porcelain dishes, a portable hot plate, a vacuum pump, a gage purging system, and a portable ultraviolet (long wave length) lamp used to detect grease (hydrocarbons) on parts and equipment to be cleaned or recleaned. The cleaning done in this area to remove hydrocarbons WILL NOT be acceptable as oxygen clean. Refer to the instruction book which comes with the equipment for best results in its usage.

The general repair area has the ultrasonic cleaning system, a hot and cold water sink, tool cabinets and lockers, and miscellaneous equipment, such as a bench-mounted grinder and drill press.

The ultrasonic cleaning system comprises three equal-sized units: ultrasonic washer, rinse unit, and hot air dryer.



NAVY CALIBRATION CHECKLIST
11ND-BWR-5512/9 (5-62)

SECTION A

1. CALIBRATING ACTIVITY
2. SUBMITTING ACTIVITY
3. TEST INSTRUMENT *(Name of Item Calibrated)*
4. MANUFACTURER
5. MODEL NUMBER *(Commercial or Military)*
6. SERIAL NUMBER
7. REASON FOR SUBMISSION
   - CERTIFICATION / CALIBRATION ☐ 1
   - CROSSCHECK ☐ 2
   - FAILURE FROM DAMAGE OR ABUSE ☐ 3
   - OPERATIONAL FAILURE ☐ 4
8. DATE OF LAST SERVICING
9. SERVICING CYCLE (MONTHS)
   - CERTIFICATION / CALIBRATION ☐
   - CROSSCHECK ☐
10. CALIBRATION PROCEDURE

SECTION B

1. CALIBRATION TECHNICIAN
2. TEST DATE
3. CONDITION RECEIVED
   - WITHIN TOLERANCE ☐ 1
   - OUTSIDE TOLERANCE *Explain Below in "REMARKS"* ☐ 2
4. CONDITION RETURNED
   - WITHIN TOLERANCE ☐ 1
   - OUTSIDE TOLERANCE *Explain Below in "REMARKS"* ☐ 2
5. CERTIFICATED OR REPORTED VALUE, IF FIXED STANDARD
6. MAN-HOURS TO CALIBRATE
7. MAN-HOURS TO REPAIR *(List Repairs in "REMARKS")*
8. SERVICING LABEL AFFIXED
   - CERTIFICATION / CALIBRATION ☐ 1
   - CROSSCHECK ☐ 2
   - LIMITED USE *(Explain Below in "REMARKS")* ☐ 3
   - REJECT ☐ 4
9. NEXT SERVICING DATE
   - CERTIFICATION / CALIBRATION
   - CROSSCHECK

SECTION C

REMARKS

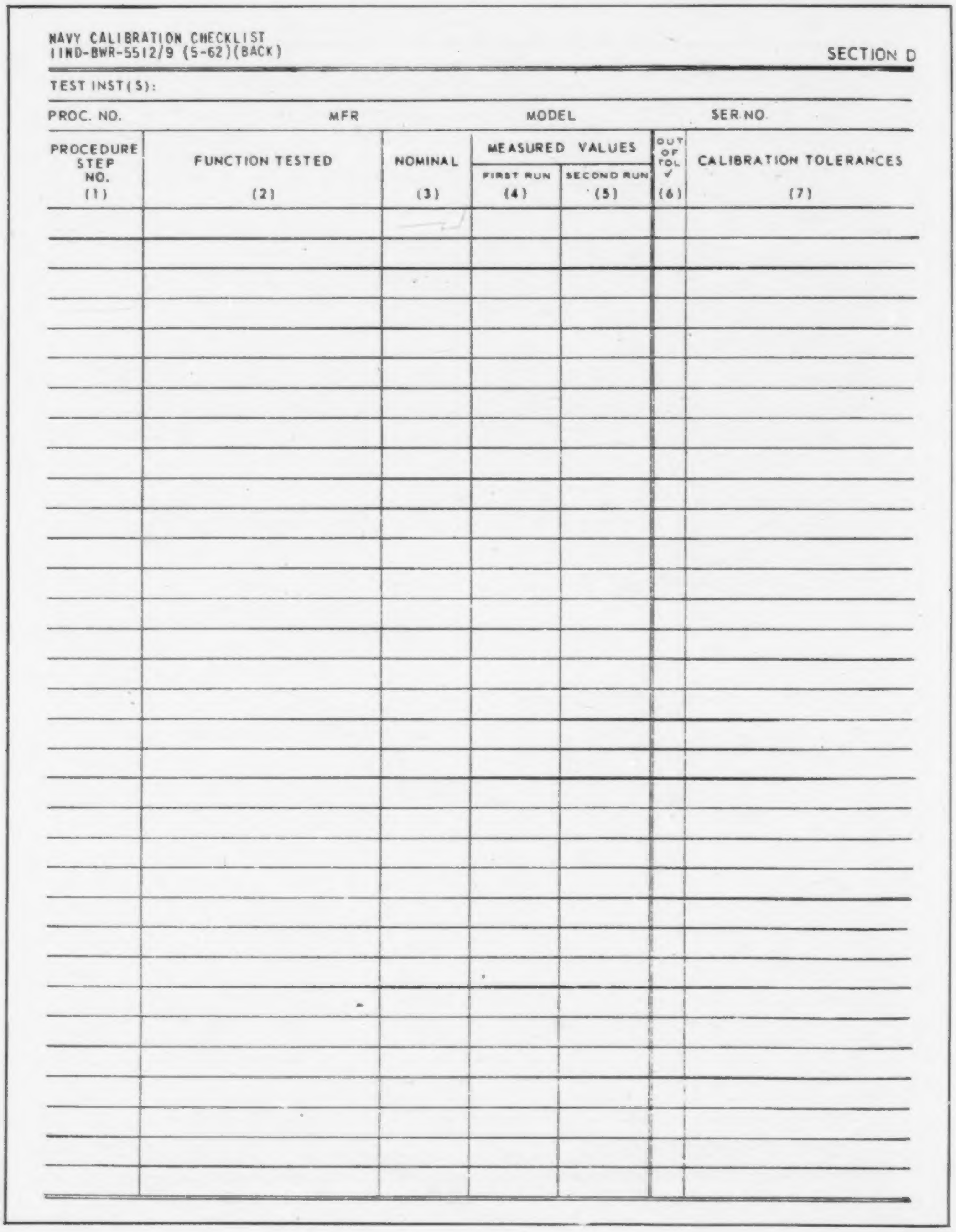
☐ REPLY TO REMARKS REQUESTED

APPROVED ____________
LABORATORY SUPERVISOR

NOTE: GENERAL INSTRUCTIONS FOR COMPLETING THIS CHECKLIST ARE PROVIDED IN *BUWEPSREP POMONA INST 4355.2*

91.558.1

Figure 4-6A. — Front Navy calibration checklist.



NAVY CALIBRATION CHECKLIST
11ND-BWR-5512/9 (5-62)(BACK)

SECTION D

TEST INST(S):

PROC. NO. MFR MODEL SER NO.

PROCEDURE STEP NO. (1)	FUNCTION TESTED (2)	NOMINAL (3)	MEASURED VALUES		OUT OF TOL ✓ (6)	CALIBRATION TOLERANCES (7)
			FIRST RUN (4)	SECOND RUN (5)		

91.558.2

Figure 4-6B. — Back Navy calibration checklist.

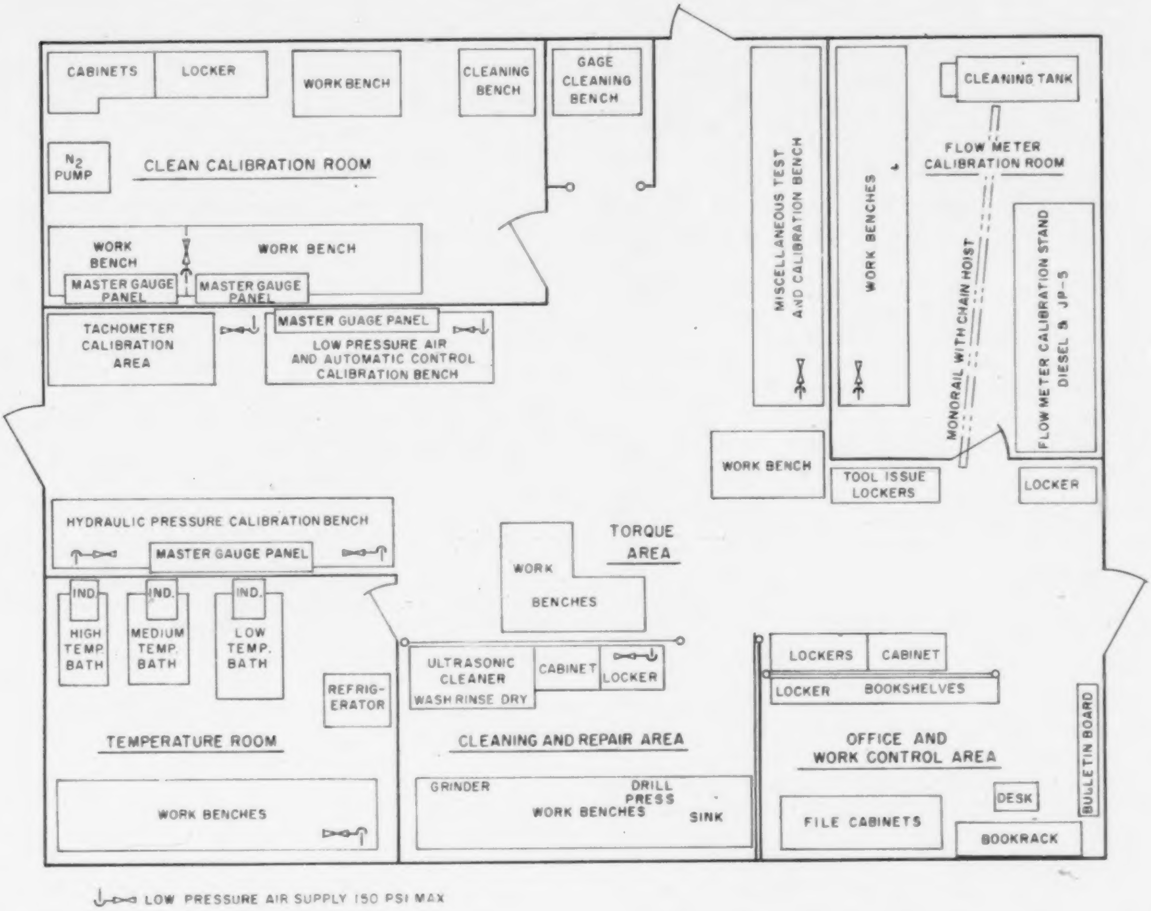

CABINETS
LOCKER
WORK BENCH
CLEANING BENCH
GAGE CLEANING BENCH
N_2 PUMP
CLEAN CALIBRATION ROOM
WORK BENCH
WORK BENCH
MASTER GAUGE PANEL
MASTER GAUGE PANEL
TACHOMETER CALIBRATION AREA
MASTER GUAGE PANEL
LOW PRESSURE AIR AND AUTOMATIC CONTROL CALIBRATION BENCH
MISCELLANEOUS TEST AND CALIBRATION BENCH
WORK BENCHES
CLEANING TANK
FLOW METER CALIBRATION ROOM
MONORAIL WITH CHAIN HOIST
FLOW METER CALIBRATION STAND DIESEL & JP-5
WORK BENCH
TOOL ISSUE LOCKERS
LOCKER
HYDRAULIC PRESSURE CALIBRATION BENCH
MASTER GAUGE PANEL
WORK BENCHES
TORQUE AREA
IND.
IND.
IND.
HIGH TEMP BATH
MEDIUM TEMP. BATH
LOW TEMP. BATH
REFRIGERATOR
TEMPERATURE ROOM
WORK BENCHES
ULTRASONIC CLEANER
WASH RINSE DRY
CABINET
LOCKER
CLEANING AND REPAIR AREA
GRINDER
DRILL PRESS
WORK BENCHES
SINK
LOCKERS
CABINET
LOCKER
BOOKSHELVES
OFFICE AND WORK CONTROL AREA
BULLETIN BOARD
DESK
FILE CABINETS
BOOKRACK
LOW PRESSURE AIR SUPPLY 150 PSI MAX

Figure 4-7.—A representative general arrangement for MIRCS. 91.559

Operating and cleaning procedures are described in the instruction manuals that accompany the equipment. In general, parts to be cleaned are distributed evenly over the bottom of a steel-meshed parts basket which is then slowly lowered until all parts are completely immersed in the cleaning solution. The length of time that a loaded basket remains in the washer varies according to the degree of soiling, position and number of parts, and type of detergent used. If more cleaning is necessary, the parts are sprayed and brushed. When the parts are clean, the basket is removed slowly so as to enable trapped liquid from the parts to be shaken off and drained. The washer lid is then closed to minimize evaporation and the basket of parts is transferred to the rinse unit. The rinse unit is an automatically controlled water pressure spraying system. After the parts have been thoroughly rinsed, water is shaken off the parts or blown off with low pressure dry air; then the parts are moved to the electrically heated dryer. It takes at least three minutes to dry the parts properly.

The cleaning solution for an ultrasonic washer consists of a mixture of 1 quart of a hard water dishwashing machine compound, 2 pounds of a non-ionic liquid detergent, and 20 gallons of hot water.

Maintenance

The tank must be cleaned periodically because residue is left by the cleaned parts.

The filter pump motor is provided with an automatic reset thermal overload. During operation, if the recirculating motor shuts down, restart the system by resetting the overload switch. If it stops again, call an Electrician's Mate to determine the cause. Do not continue to engage the overload switch.

The filter pump motor seal is a cartridge type seal that can be removed and replaced as a unit.

The filter pump controls the recirculation action of the cleaning solution through the filter element. It does not operate during the period of ultrasonic energy activation. The filter in the recirculating system can be replaced without draining the system.

A high line voltage will shut down the generator of the ultrasonic cleaner, as will the thermostat control. First, check the fuse at the rear of the generator if the generator system shuts down. If the fuse is good, then the trouble is probably in the washer.

TACHOMETER CALIBRATION AREA

This area has a self-contained bench-mounted tachometer calibrator for use with mechanical and electrical tachometers. It can test three instruments simultaneously, within specified speed ranges, through the use of flexible shafts, tachometer generators or magnetos, and adapters. Minimum speed can be obtained using a stepdown device with a 5-to-1 ratio; maximum speed by using a step-up device having a 1-to-2 ratio.

A stroboscope disc is provided to indicate motor output speed, expressed in revolutions per minute (rpm) for accurate calibration. A master tachometer indicator enables the operator to check the stroboscope disc speed to prevent reading errors.

The range of the tachometer calibrator is 36 rpm to 10,000 rpm; calibration increments are in multiples of 50, 100, 200, and 400 rpm, depending on the output drive in use.

The accuracy of the indication of the stroboscopic disc is ±0.1% of the indicated reading, only if line frequency is accurate within 0.1%. The master tachometer indicator is accurate to within ±1% of the full scale in use.

Have the tachometer calibrator checked on a 36-month cycle at a Fleet Electronics Calibration Laboratory (FECL) or higher standard laboratory.

For further information, refer to the manufacturer's technical manual. Always follow the maintenance instructions. Instrumentman 3 & 2, NAVPERS 10193-C, Chapter 8, covers operation, maintenance, and use of the tachometer calibrator and tachometers.

TORQUE AREA

The torque area is equipped with two dual-range torque wrench testers and one single-range tester. One of the dual-range testers has ranges from 0 to 100 oz in. and 0 to 500 oz in., graduated in 0.5 oz in. increments. The other dual-range torque tester has ranges from 0 to 250 lb in. and 0 to 2000 lb in., graduated in 0.25 lb in. increments. The single-range torque tester has a range of 0 to 1,000 lb ft graduated in increments of 1 lb ft. The limit of error for each of the three torque testers is ±1% or one scale graduation, whichever is greater for the indicated value.

The required calibration cycle for the torque testers is 6 months. The torque testers may be calibrated at Navy calibration facilities that have the required equipment. Calibration of the torque testers may be accomplished in MIRCS if the appropriate torque calibrator is available. Normally, this calibrator will be available and may be borrowed from other Navy calibration facilities.

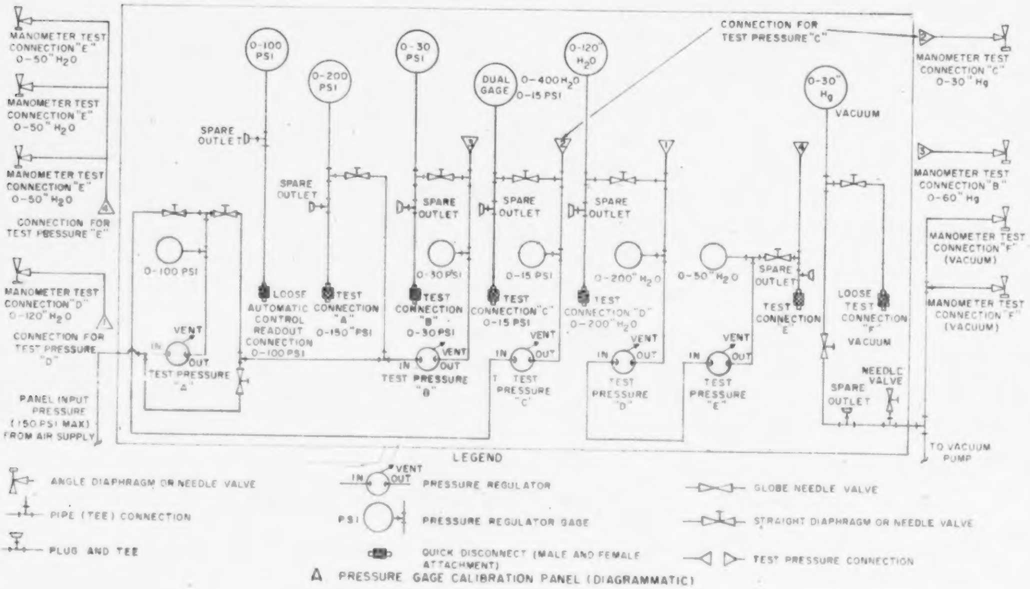
LOW PRESSURE CALIBRATION AREA

The low pressure calibration system, figure 4-8, consists of a multigage panel, containing dial manometers, vacuum gages, and other low pressure gages. In addition to the panel, the area contains U-tube manometers, a vacuum chamber, and various other portable low pressure instruments. The system is used to test and calibrate gages having ranges from 30.0 inches of mercury vacuum (0 absolute) to 200 psig.

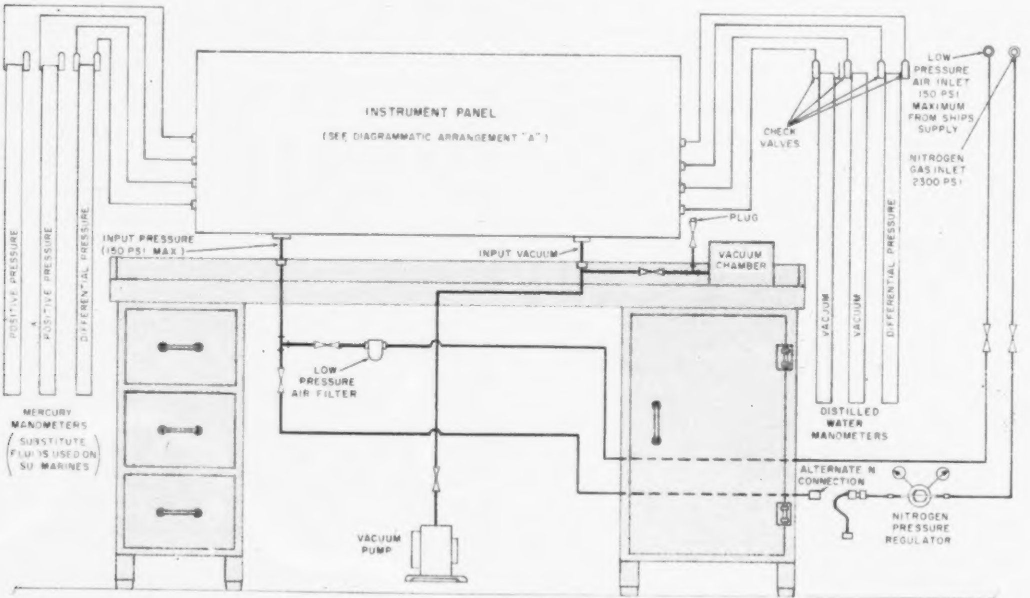
The gage panel uses shipboard low pressure air and nitrogen as test media. A vacuum pump is connected into the system to produce desired vacuum.

The U-tube manometers, filled with either mercury or colored distilled water, are used to measure vacuum, differential pressures, absolute pressures and positive pressures.

The master gages in the low pressure panel have a calibration cycle of 6 months, using the appropriate shop standard.


MANOMETER TEST CONNECTION "E" 0-50" H2O
MANOMETER TEST CONNECTION "E" 0-50" H2O
MANOMETER TEST CONNECTION "E" 0-50" H2O
CONNECTION FOR TEST PRESSURE "E"
MANOMETER TEST CONNECTION "D" 0-120" H2O
CONNECTION FOR TEST PRESSURE "D"
PANEL INPUT PRESSURE (150 PSI MAX) FROM AIR SUPPLY
0-100 PSI
0-200 PSI
0-30 PSI
DUAL GAGE
0-400 H2O 0-15 PSI
0-120" H2O
0-30" Hg
VACUUM
CONNECTION FOR TEST PRESSURE "C"
MANOMETER TEST CONNECTION "C" 0-30" Hg
MANOMETER TEST CONNECTION "B" 0-60" Hg
MANOMETER TEST CONNECTION "F" (VACUUM)
MANOMETER TEST CONNECTION "F" (VACUUM)
SPARE OUTLET
0-100 PSI
0-30 PSI
0-15 PSI
0-200" H2O
0-50" H2O
LOOSE AUTOMATIC CONTROL READOUT CONNECTION 0-100 PSI
TEST CONNECTION "A" 0-150" PSI
TEST CONNECTION "B" 0-30 PSI
TEST CONNECTION "C" 0-15 PSI
TEST CONNECTION "D" 0-200" H2O
TEST CONNECTION "E"
LOOSE TEST CONNECTION "F" VACUUM
VENT
IN
OUT
TEST PRESSURE "A"
TEST PRESSURE "B"
TEST PRESSURE "C"
TEST PRESSURE "D"
TEST PRESSURE "E"
NEEDLE VALVE
SPARE OUTLET
TO VACUUM PUMP
LEGEND
ANGLE DIAPHRAGM OR NEEDLE VALVE
PIPE (TEE) CONNECTION
PLUG AND TEE
PRESSURE REGULATOR
PSI
PRESSURE REGULATOR GAGE
QUICK DISCONNECT (MALE AND FEMALE ATTACHMENT)
GLOBE NEEDLE VALVE
STRAIGHT DIAPHRAGM OR NEEDLE VALVE
TEST PRESSURE CONNECTION

A PRESSURE GAGE CALIBRATION PANEL (DIAGRAMMATIC)


INSTRUMENT PANEL
(SEE DIAGRAMMATIC ARRANGEMENT "A")
POSITIVE PRESSURE
POSITIVE PRESSURE
DIFFERENTIAL PRESSURE
MERCURY MANOMETERS
(SUBSTITUTE FLUIDS USED ON SUBMARINES)
INPUT PRESSURE (150 PSI MAX)
INPUT VACUUM
PLUG
VACUUM CHAMBER
CHECK VALVES
LOW PRESSURE AIR INLET 150 PSI MAXIMUM FROM SHIPS SUPPLY
NITROGEN GAS INLET 2300 PSI
VACUUM
VACUUM
DIFFERENTIAL PRESSURE
DISTILLED WATER MANOMETERS
LOW PRESSURE AIR FILTER
ALTERNATE N CONNECTION
NITROGEN PRESSURE REGULATOR
VACUUM PUMP

B AIR PRESSURE CALIBRATION BENCH (PICTORIAL)

91.560

Figure 4-8.—Low pressure air and automatic control gage calibration system.

Nature of Atmospheric Pressure

The standard atmospheric pressure is actually an average value above absolute zero, measured at sea level. It is based upon many readings taken under general conditions at various locations. Changes in atmospheric conditions, even at sea level, will vary the exact value of atmospheric pressure. Figure 4-9 gives the average atmospheric pressures at various altitudes; observe that by 3,000 feet it is down to 13.178 psia and by 10,000 feet it is down to 10.108 psia.

The torr (named in honor of Evangelista Torricelli, who devised the first barometer, figure 4-10) has recently been designated as the standard unit of measure of vacuum. The torr is defined as 1/760 of a standard atmosphere. Since a standard atmosphere is not quite 760 mm Hg, one torr is not exactly equal to one millimeter of mercury, but the difference is so small (parts per million) that the terms can be used interchangeably. Another commonly used term in vacuum measurements is the micron (μ), which is equal to 10^{-3} torr or 10^{-3} mm Hg.

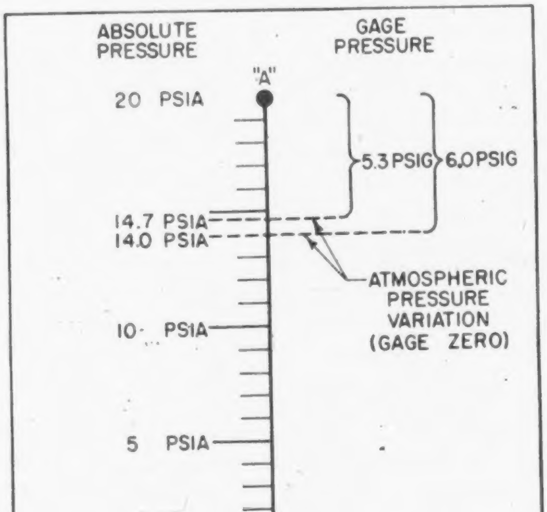


Figure 4-9. — Effect of atmospheric pressure change on gage zero. 91.561

Consider now exactly how any change in atmospheric pressure affects a gage pressure measurement or a vacuum gage measurement. Referring to figure 4-11, an absolute pressure value of 20 psia (point "A"), would be equivalent to a pressure of 5.3 psig when the atmospheric pressure is the standard 14.7 psia. If the barometric pressure dropped to 14.0 psia, the equivalent gage pressure would be 6.0 psig.

A gage measuring gage pressure would change its reading by 0.7 psi. Where an exact measure of the pressure in a vessel is desired, this could be an intolerable error. Either use an absolute pressure gage which automatically compensates for changes in atmospheric pressure, or obtain an exact reading of the barometric pressure and correct your gage pressure measurement, subtracting the 0.7 psi from the indicated 6.0 psig when the barometer reads 14.0 psia.

On the otherhand, in an application where the pressure is in the order of 3,000 psig, the 0.7 psi error referred to above is obviously of no importance. Even the finest and most accurate gages do not measure so accurately that 0.7 psi in 3,000 is significant. It is not until the measured pressures get below 100 or 200 psi (depending on the accuracy of the reading) that the effects of changes in atmospheric pressure need be considered. Even then it is the unusual case that such changes need be taken into consideration. The majority of gages measure gage pressure or vacuum, and compensation for changes in atmospheric pressure is not made.

Figure 4-12 shows the relation between gage or vacuum readings and the corresponding value of absolute pressure. Essentially, a gage pressure can be converted to absolute pressure by adding the value of atmospheric pressure (in the same units, such as "pounds per square inch"). The 50 pounds per square inch gage pressure, as shown, corresponds to 64.7 pounds per square inch absolute, assuming a standard atmosphere.

Similarly, vacuum readings can be converted to absolute pressure by subtracting the vacuum reading from the atmospheric pressure. For example, suppose the vacuum gage reads 10 inches of mercury vacuum. Subtract it from the atmospheric pressure to convert to absolute pressure (assume the latter is the standard 29.92 inches of mercury absolute). A value of

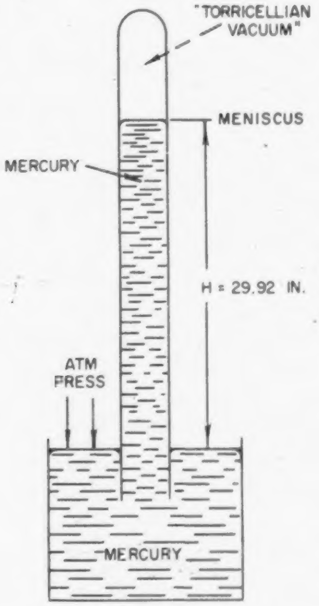
Altitude Above Sea Level - Feet	Average Atmospheric Pressure	
	Inches of Mercury (abs.)	Pounds per Square Inch (abs.)
0	29.921	14.696
500	29.400	14.440
1,000	28.879	14.184
1,500	28.357	13.928
2,000	27.836	13.672
2,500	27.315	13.416
3,000	26.831	13.178
3,500	26.348	12.941
4,000	25.864	12.703
4,500	25.381	12.466
5,000	24.897	12.228
5,500	24.449	12.008
6,000	24.001	11.788
6,500	23.552	11.568
7,000	23.104	11.348
7,500	22.656	11.128
8,000	22.241	10.924
8,500	21.826	10.720
9,000	21.411	10.516
9,500	20.996	10.312
10,000	20.581	10.108
10,500	20.197	9.9200
11,000	19.814	9.7318
11,500	19.430	9.5432
12,000	19.047	9.3551
12,500	18.663	9.1665
13,000	18.309	8.9926
13,500	17.955	8.8188
14,000	17.601	8.6449
14,500	17.247	8.4710
15,000	16.893	8.2972
15,500	16.567	8.1370
16,000	16.241	7.9769
16,500	15.914	7.8163
17,000	15.588	7.6562
17,500	15.262	7.4961
18,000	14.962	7.3487
18,500	14.662	7.2014
19,000	14.361	7.0535
19,500	14.061	6.9062
20,000	13.761	6.7589

91.562

Figure 4-10.—Average atmospheric pressures at various altitudes.

19.9 inches mercury absolute would be obtained. These two equivalent pressures are shown as point "A" in figure 4-12.

Differential pressure is also illustrated in figure 4-12. Gages are available to measure and indicate the difference between two measured pressures, such as "B" (10 psig) and "C" (40 psig). The differential pressure gage indicates the difference (in this case 30 psi) on a scale that would read "zero" when the two pressures are equal—regardless of their individual values. The zero point may be in the center of the scale to permit readings in one direction or the other, depending upon which pressure is greater. If one of the two pressures is always the greater of the two, the zero point may be at the beginning of the scale. Because such gages read the difference between two pressures, the distinction between gage or absolute pressure does not matter; variations in atmospheric pressure do not affect the readings, because both are similarly


"TORRICELLIAN VACUUM"
MENISCUS
MERCURY
H = 29.92 IN.
ATM PRESS
MERCURY

69.86

Figure 4-11.—First barometer devised by Evangelista Torricelli.

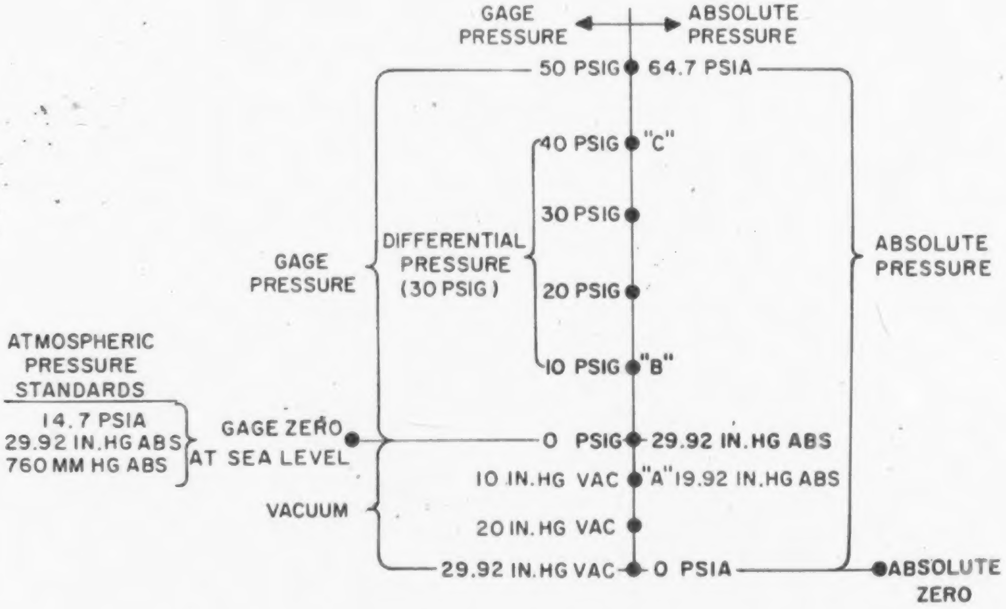
affected. Actually, common pressure gages act as differential pressure gages by measuring the difference between atmospheric pressure and the pressure being measured.

Gages which measure absolute pressure are not affected by changes in atmospheric pressure; they measure the absolute value from an unchanging absolute zero. In the case of gage pressure or vacuum, however, the gage measures the difference between the absolute value and atmospheric pressure. Hence, if the atmospheric pressure changes, readings of gage pressure or vacuum will change, for a given absolute pressure.

The actual importance of changes in atmospheric pressure depends upon the required accuracy of gage readings and the amount of the pressure whether it is low or high.

MISCELLANEOUS TEST AND CALIBRATION AREA

In the miscellaneous test and calibration area are located MIRCS primary or reference pressure standards, such as deadweight piston gages (commonly known as deadweight testers).


GAGE PRESSURE
ABSOLUTE PRESSURE
50 PSIG
64.7 PSIA
40 PSIG
"C"
30 PSIG
DIFFERENTIAL PRESSURE (30 PSIG)
GAGE PRESSURE
20 PSIG
ABSOLUTE PRESSURE
10 PSIG
"B"
ATMOSPHERIC PRESSURE STANDARDS
14.7 PSIA
29.92 IN.HG ABS
760 MM HG ABS
GAGE ZERO AT SEA LEVEL
0 PSIG
29.92 IN.HG ABS
10 IN.HG VAC
"A" 19.92 IN.HG ABS
VACUUM
20 IN.HG VAC
29.92 IN.HG VAC
0 PSIA
ABSOLUTE ZERO

147.181(91C)

Figure 4-12.—Comparison of gage and absolute pressure.

Primary Standards

A primary standard must refer directly to mass (force), length, and time. Deadweight testers, with proper calibration, are considered primary standards. Since they meet the requirements. The best bourdon tubes or diaphragm gages, however, are classified as secondary standards in that they do not refer directly to mass, length, and time.

Deadweight Testers

There are several types of deadweight testers. The types are determined by whether the pressure medium is fluid or gas. The fluid type deadweight testers use oil or water as the pressure medium; bifluid deadweight testers use oil and water. Pneumatic deadweight testers use a gas, usually pure nitrogen, as the pressure medium.

Care and Maintenance of Hydraulic Deadweight Testers

Since the construction details vary for each make tester, the manufacturers' catalog or the NavShips Technical Manual should be read for specific care and maintenance information. In addition, the following factors should be observed or considered:

1. Handle the weights carefully and keep them in the case provided when they are not in use.
2. Handle the piston and cylinder assemblies (very accurately fitted parts) carefully. If it is necessary to replace the piston or cylinder, the entire assembly must be replaced. It is impracticable to replace either the piston or the cylinder separately.
3. Do not operate the pump or ram without fluid because it is required as a lubricant for component parts of the system.
4. Flush the reservoir periodically and renew the operating fluid.
5. When operating with water, keep the system free of oil. Even a small amount of oil will develop a scum or emulsion on the deadweight piston and cause a sluggish rotation of the piston. If this occurs, remove the piston and cylinder. Wipe the piston with clean soft paper and work it in the cylinder several times; this will generally clean off the scum or emulsion. Then replace the piston and cylinder in the tester.
6. Replace defective or worn "O" rings in the system. The most common cause of leakage, failure to pump, or failure to hold pressure results from defective or worn "O" rings.
7. If the pump is dry or runs out of fluid, it may be necessary to prime the system and to vent all air.
8. See that flexible connectors are in satisfactory condition and rated for the pressures at which they are used.

Calibration of Deadweight Testers

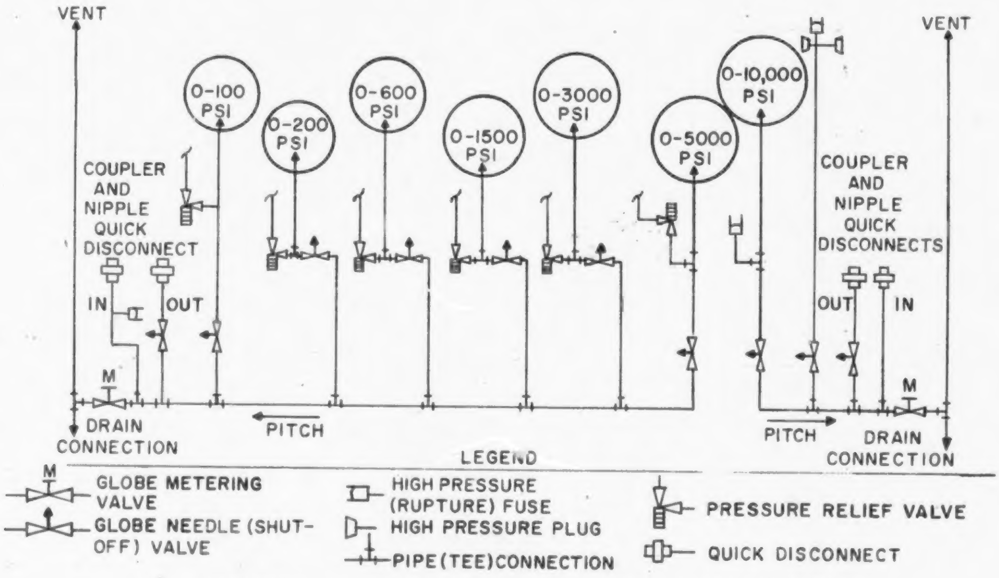
Deadweight testers are not readily calibrated aboard ship because extremely precise measurements are required. The units are sent to shipyard calibration laboratories or Navy standards laboratories when calibration of testers is required.

CALIBRATION TECHNIQUES.—When calibrating low pressure deadweight testers, a calibration laboratory determines mass of weights and pistons, measures the inside and outside diameters of the cylinders and pistons and computes mean area. In calibrating a high pressure deadweight tester, the laboratory cross floats the tester against a standard tester. When the two testers are in equilibrium, the true pressure of the standard tester is the true pressure of the test instrument. If the mass of the weights for the test instrument are known, the effective area (A_e) of the piston, of the test instrument at different cross float pressures is computed. The deformation coefficient of the test instrument's piston is computed by noting the change in effective area (A_e) at different cross float pressures.

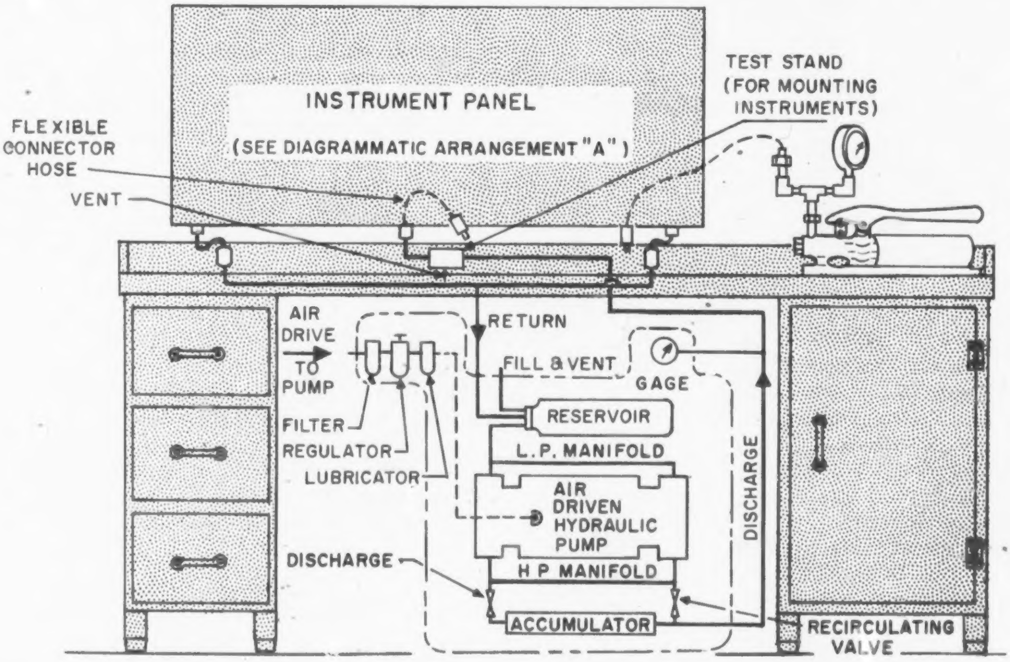
REPORT OF CALIBRATION.—The calibration laboratory returns the calibrated deadweight tester with a report of calibration. See appendix I which contains a sample report and a supplement to the report of calibration. The supplement points out errors in the use of the deadweight tester and explains to the operator how to apply proper corrections for the errors.

HYDRAULIC CALIBRATION AREA

The hydraulic pressure gage calibration system, figure 4-13, is a multigage (water) panel with distinct low and high pressure sides. The low pressure side is capable of operating at pressures up to 5,000 psi and the high pressure side is capable of operating up to 10,000 psi. Seven master gages are used for testing or


VENT
0-100 PSI
0-200 PSI
0-600 PSI
0-1500 PSI
0-3000 PSI
0-5000 PSI
0-10,000 PSI
VENT
COUPLER AND NIPPLE QUICK DISCONNECT
IN
OUT
M
DRAIN CONNECTION
PITCH
COUPLER AND NIPPLE QUICK DISCONNECTS
OUT
IN
M
PITCH
DRAIN CONNECTION
LEGEND
M
GLOBE METERING VALVE
GLOBE NEEDLE (SHUT-OFF) VALVE
HIGH PRESSURE (RUPTURE) FUSE
HIGH PRESSURE PLUG
PIPE(TEE)CONNECTION
PRESSURE RELIEF VALVE
QUICK DISCONNECT

A. PRESSURE GAGE CALIBRATION PANEL (DIAGRAMMATIC)


INSTRUMENT PANEL
(SEE DIAGRAMMATIC ARRANGEMENT "A")
TEST STAND (FOR MOUNTING INSTRUMENTS)
FLEXIBLE CONNECTOR HOSE
VENT
AIR DRIVE TO PUMP
RETURN
FILL & VENT
GAGE
FILTER
REGULATOR
LUBRICATOR
RESERVOIR
L.P. MANIFOLD
AIR DRIVEN HYDRAULIC PUMP
H P MANIFOLD
DISCHARGE
DISCHARGE
ACCUMULATOR
RECIRCULATING VALVE

B HYDRAULIC PRESSURE CALIBRATION BENCH (PICTORIAL)

91.563

Figure 4-13.—Hydraulic pressure gage calibration system.

calibrating hydraulic test instruments with low-side ranges of 0-100 psi, 0-200 psi, 0-600 psi, 0-1,500 psi, 0-3,000 psi, and 0-5,000 psi, and a high-side range of 0-10,000 psi.

The panel is generally operated by an air-driven, floor-mounted, hydraulic pump assembly that is capable of producing pressures to 10,000 psi.

The panel may be operated with a bench-mounted hydraulic hand pump assembly that is capable of producing pressures of 0-15,000 psi. Either pump may be connected to the system with a high pressure flexible hose and quick-disconnect fittings.

The master gages in the hydraulic panel have a calibration cycle of 6 months with shop standards (deadweight tester). The accuracy of the master gages is 0.1% of full scale reading.

CLEAN CALIBRATION AREA

The clean room contains two multigage panels as shown in figure 4-14. Both use dry, water-pumped nitrogen as the calibration medium. The low and medium pressure panel is divided into a low pressure section and a medium pressure section. The low pressure section consists of three master gages, with ranges of 0-100 psi, a dual-range master gage of 0-400 inches of H_2O and 0-15 psi, and a 0-120 inches of H_2O gage. The medium pressure section has three master gages whose ranges are 0-200 psi, 0-600 psi, and 0-1,000 psi. In the high pressure panel, the ranges of the master gages are 0-1,500 psi and 0-3,000 psi in one section, and 0-5,000 psi and 0-10,000 psi in the other section.

The master gages in the panels have a calibration cycle of 6 months. The accuracy of the master gages is 0.1% of full scale reading.

The following rules are to be strictly adhered to by those working in the clean room:

1. Ensure that all equipment, tools, and items to be calibrated are inspected for contamination and verified "clean" before they are brought into the clean room.
2. Tag or mark all completed work "clean" and seal open end of gages or equipment with poly-bag or caps.
3. Keep all openings of test equipment sealed or covered, when not in use.
4. Ensure that tools, workbenches, and hands are kept clean and free of hydrocarbons at all times.
5. Use no oil or grease.
6. Use no cutting tools, such as drills, files, saws, or abrasives.
7. Do not smoke, eat, or drink.

Due to current limitations in detecting or determining the amount of hydrocarbon present in or on "clean" equipment, users of the calibration system for clean room gages must follow the current NAVSHIPS Instruction.

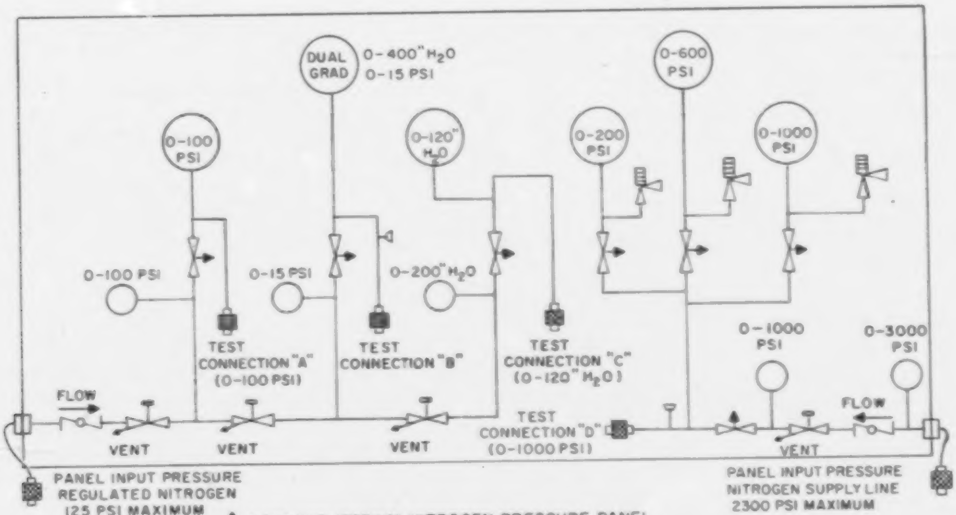
Nitrogen Booster

The nitrogen booster, figure 4-15, is an air-driven nitrogen pump. Its purpose is to pressurize nitrogen gas up to 10,000 psi without contamination by hydrocarbons. The nitrogen supply to the booster consists of a bank of nitrogen bottles or another nitrogen source, charged with water-pumped nitrogen. The supply is connected to a manifold which has a line leading from it to the low and medium pressure gage panel and to the nitrogen booster pump. The booster pump requires at least 800 psig of nitrogen to operate. Air pressure to drive the pump must be at least 70 psig, but no greater than 120 psig.

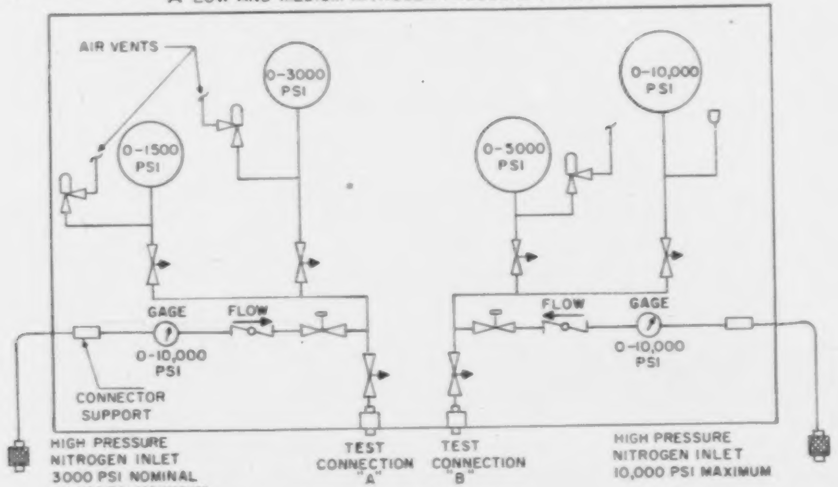
Figure 4-16 is a diagram of an air-driven nitrogen booster. The booster comprises an air-drive system and a nitrogen system.

The air-drive system consists of the filter to remove impurities and moisture from the air, the regulator to control the speed of the pumping action, and the lubricator to keep the moving parts of the air system lubricated. In the pump, a four-way valve controls the direction of air flow in the air cylinder and, in turn, controls the direction of the air system. The air piston in the pump is double acting, but non-cushioned. The plunger (part of the nitrogen system) is connected to the lower end of the air piston.

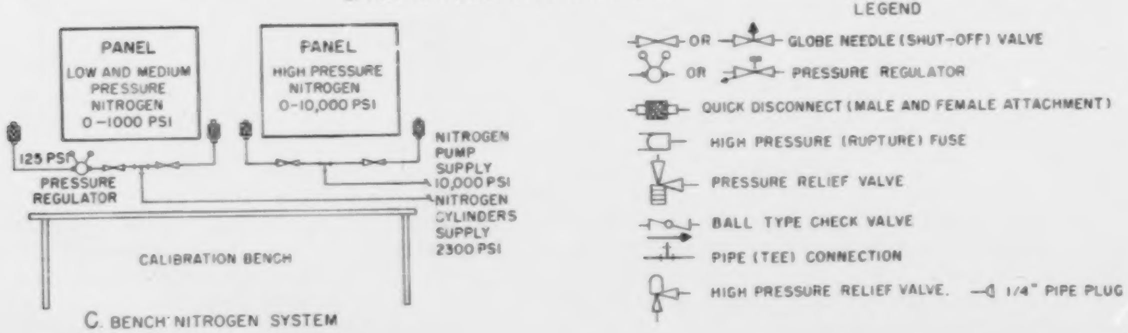
The nitrogen system has a gas filter which contains woven stainless steel elements that are easily cleaned or replaced. They are threaded assemblies and can be screwed in and out. There are two types of check valves used in the nitrogen system. Both types should be disassembled, inspected, and cleaned periodically. Any leakage of the check valves will cause a loss of output pressure. In the ball type check valve, the seat is removable for remachining or lapping if it leaks. The poppet type is spring loaded with a teflon "O" ring and gasket. If it leaks, replacement of the "O" ring and gasket is necessary. The compressor stuffing


DUAL GRAD
0-400" H2O
0-15 PSI
0-600 PSI
0-100 PSI
0-120" H2O
0-200 PSI
0-1000 PSI
0-100 PSI
0-15 PSI
0-200" H2O
TEST CONNECTION "A" (0-100 PSI)
TEST CONNECTION "B"
TEST CONNECTION "C" (0-120" H2O)
0-1000 PSI
0-3000 PSI
FLOW
VENT
VENT
VENT
TEST CONNECTION "D" (0-1000 PSI)
VENT
FLOW
PANEL INPUT PRESSURE REGULATED NITROGEN 125 PSI MAXIMUM
PANEL INPUT PRESSURE NITROGEN SUPPLY LINE 2300 PSI MAXIMUM

A LOW AND MEDIUM NITROGEN PRESSURE PANEL.


AIR VENTS
0-3000 PSI
0-1500 PSI
0-10,000 PSI
0-5000 PSI
GAGE
FLOW
0-10,000 PSI
CONNECTOR SUPPORT
FLOW
GAGE
0-10,000 PSI
HIGH PRESSURE NITROGEN INLET 3000 PSI NOMINAL 10,000 PSI MAXIMUM
TEST CONNECTION "A"
TEST CONNECTION "B"
HIGH PRESSURE NITROGEN INLET 10,000 PSI MAXIMUM

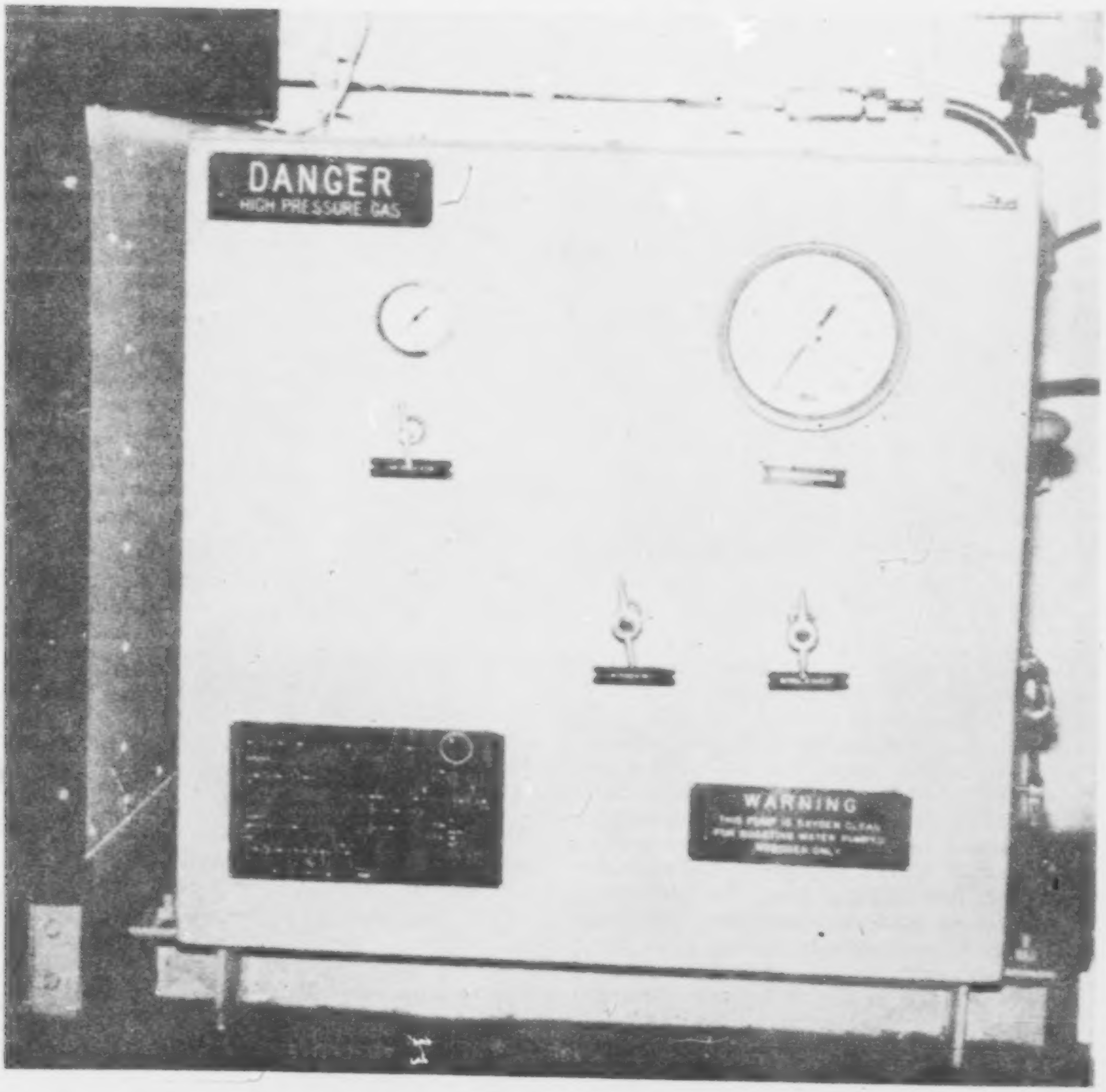
B HIGH NITROGEN PRESSURE PANEL


PANEL
LOW AND MEDIUM PRESSURE NITROGEN 0-1000 PSI
PANEL
HIGH PRESSURE NITROGEN 0-10,000 PSI
125 PSI
PRESSURE REGULATOR
NITROGEN PUMP SUPPLY 10,000 PSI
NITROGEN CYLINDERS SUPPLY 2300 PSI
CALIBRATION BENCH
LEGEND
OR GLOBE NEEDLE (SHUT-OFF) VALVE
OR PRESSURE REGULATOR
QUICK DISCONNECT (MALE AND FEMALE ATTACHMENT)
HIGH PRESSURE (RUPTURE) FUSE
PRESSURE RELIEF VALVE
BALL TYPE CHECK VALVE
PIPE (TEE) CONNECTION
HIGH PRESSURE RELIEF VALVE.
1/4" PIPE PLUG

C. BENCH NITROGEN SYSTEM

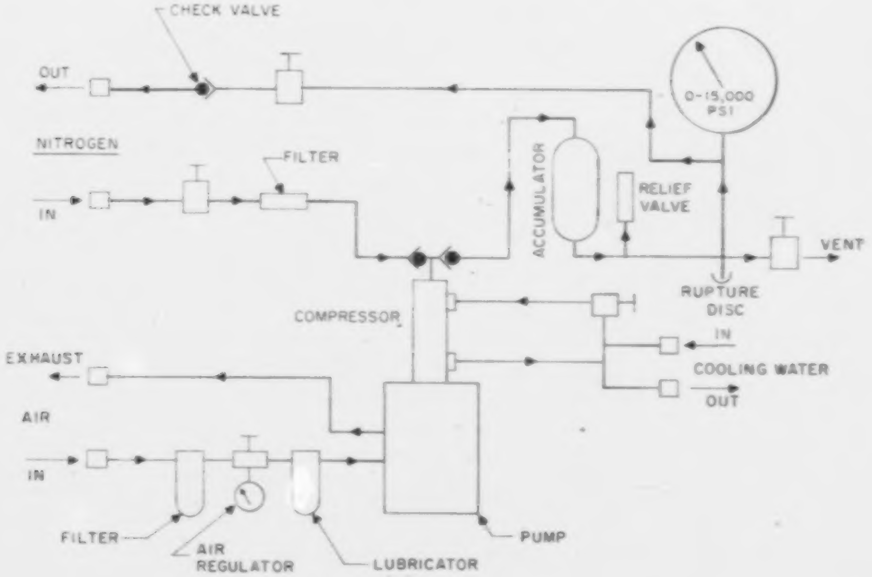
91.564

Figure 4-14.—Clean room pressure gage calibration system.


DANGER
HIGH PRESSURE GAS
WARNING

91.565

Figure 4-15.—10,000 psi nitrogen booster.



91.566

Figure 4-16.—Air driven nitrogen booster.

box contains the teflon plunger, sealing ring, "O" rings, and backup rings. It is provided with a cooling jacket (water cooled) to dissipate the heat generated by the nitrogen being compressed. The plunger is a positive displacement, reciprocating rod driven by the air piston and operates within the stuffing box. The accumulator is a 20-cubic inch stainless steel cylinder which has been hydrostatically tested at 22,500 psi. The relief valve, is set to lift at 10,500 psi. Check the setting of the relief valve before operating the unit. The rupture disc serves as a backup for the relief valve and ruptures at 12,000 psi. The nitrogen discharge gage indicates the amount of pressure in the accumulator. The gage requires calibration each 6 months.

FLOW CALIBRATION AREA

The flow calibration installation is made only on ARs that are required to furnish flow calibration services. The flow calibration system consists of a calibration stand (fig. 4-17), a cleaning system for flowmeters, and a portable flow calibrator to test water flowmeters in place in a system.

For more information on the flow calibration system, flowmeters, and repair practices, refer to chapter 10 of Instrumentman 3 & 2, NAVPERS 10193-C.

TEMPERATURE CALIBRATION AREA

The temperature calibration area contains systems for testing and calibrating temperature-measuring devices. Before going further, you should review the principles of these devices in chapter 7 of Instrumentman 3 & 2, NAVPERS 10193-C.

ASTM Standards

These are reference standards, liquid-in-glass thermometers, manufactured in strict accordance with American Society for Testing and Materials (ASTM) precision specifications. Table 4-1 gives characteristics of these thermometers, a set of nine thermometers in overlapping ranges of temperature coverage of -36°F to +761°F or Celsius equivalent. Caution should be taken not to exceed the maximum range of the thermometer in use. The thermometers are total immersion type. With the exception of the first

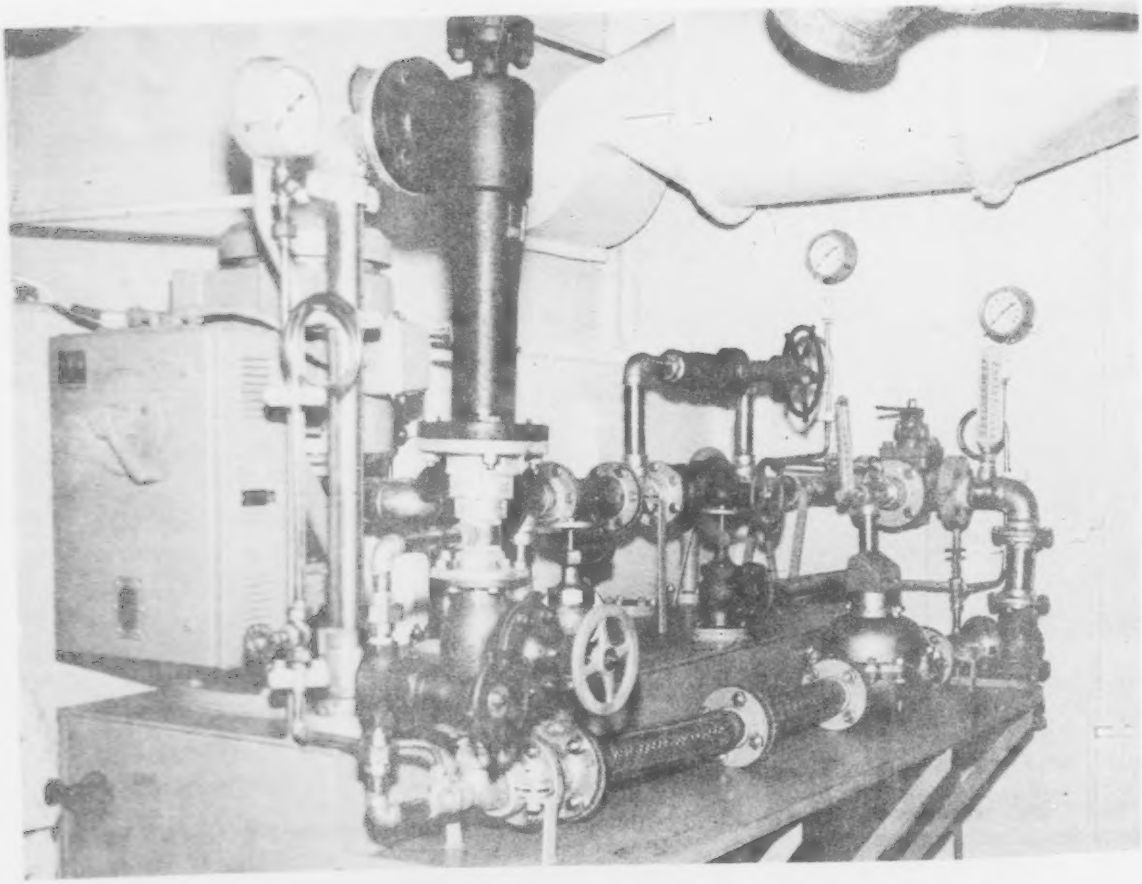
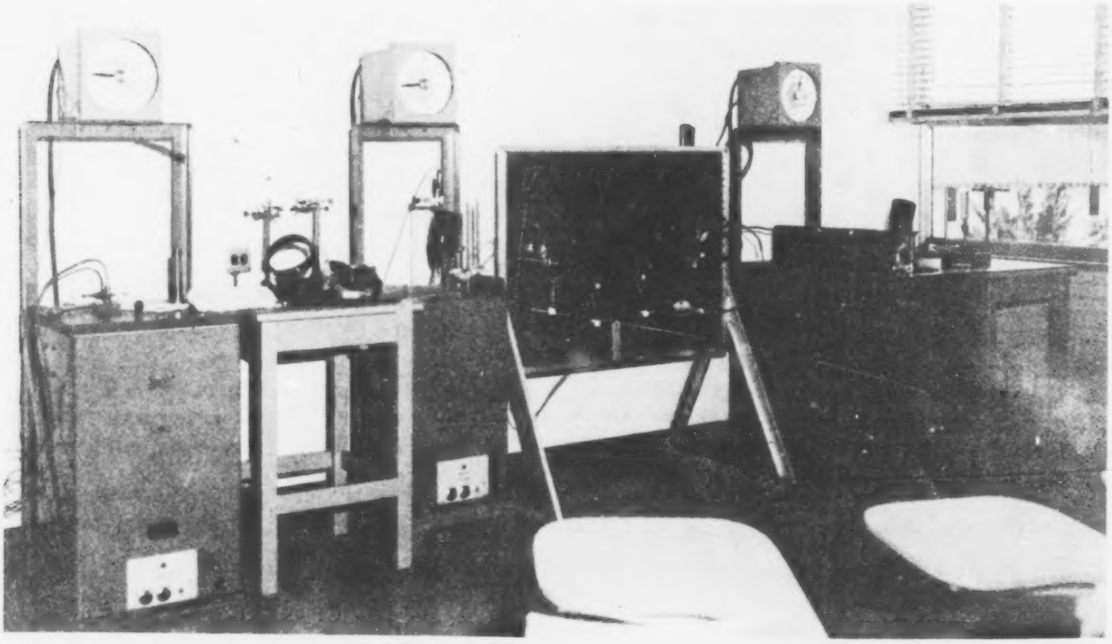


Figure 4-17. — Flow calibration stand. 91.567

Table 4-1. – Reference Standards Liquid-in-Glass Thermometers

ASTM	Range (°F)	Divisions (°F)	Length (mm)	Accuracy (°F)
62 F	-36 to +35	0.2	380	.05
63 F	18 to 89	0.2	380	.05
64 F	77 to 131	0.2	380	.05
65 F	122 to 176	0.2	380	.05
66 F	167 to 221	0.2	380	.05
67 F	203 to 311	0.5	380	.2
68 F	293 to 401	0.5	380	.2
69 F	383 to 581	1.0	380	.5
70 F	563 to 761	1.0	380	.5

91.568



61.165(91C)

Figure 4-18. — Temperature area.

two, each thermometer is provided with an auxiliary scale which includes 32° F or Celsius equivalent. Thus, each of the thermometers in this series is provided with a means for checking the ice point, which should be done from time to time when the thermometer is used.

The ASTM thermometers are used in calibration of shop working standards (resistant thermometer indicators) and other temperature measuring instruments requiring a high degree of accuracy. Other uses for these thermometers are in other calibration areas of MIRCs on equipment requiring temperature corrections. However, they are being deleted from MIRCS (as a mercury hazard) and are being replaced with additional platinum and/or copper resistance thermometer.

Thermometer Calibration Baths

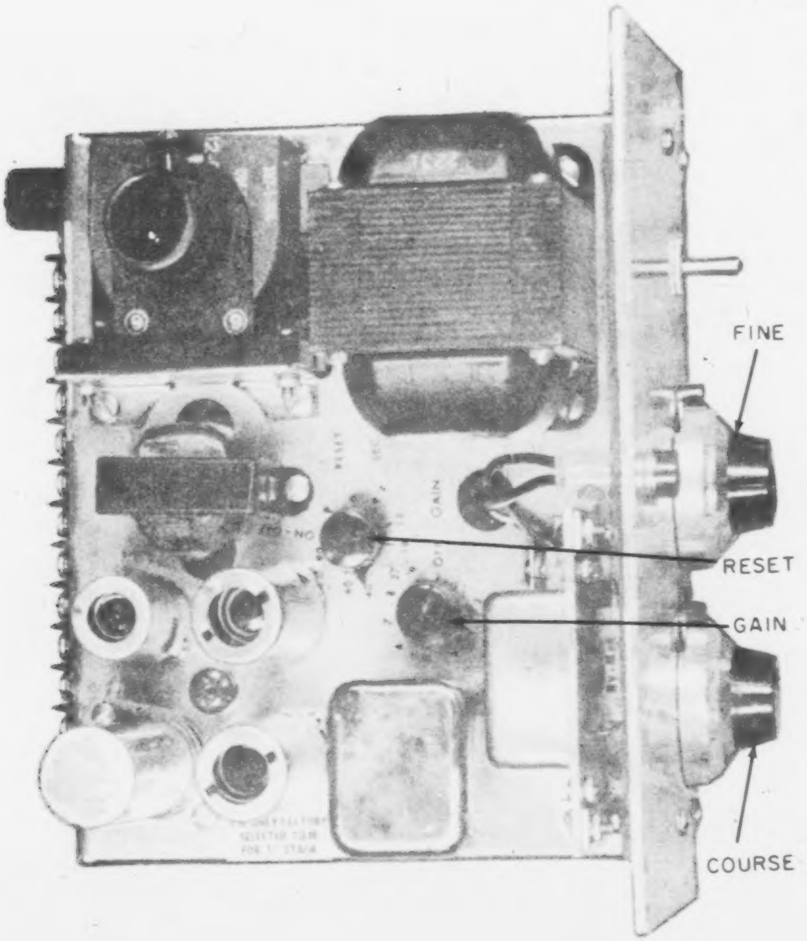
Three baths (fig. 4-18) are located in the temperature calibration area. A low bath is used on calibrations from -40° F to 200° F, a medium bath from ambient temperature to 500° F, and a high bath from 400° F to 1,000° F.

The low and medium baths use silicone oil as the medium for heat transfer; the high bath uses molten salt or sand (heat treated). CAUTION: Water, oil, moisture, etc in the salt will cause bubbles to form or an explosion when the salt is heated.

The high or medium bath uses a platinum resistance thermometer as its sensing element; the low bath uses a copper resistance thermometer. In thermometer calibration the element end of the resistance thermometer is immersed in the bath medium; the lead end is connected to the appropriate resistance thermometer indicator.

A stainless steel cooling coil for use with tap water is provided in the medium baths to lower the bath temperature rapidly. The cooling coil also enables the bath to be operated at a few degrees below ambient temperature. A refrigeration unit in the low temperature bath is used for cooling to -40° F or °C.

Each thermometer calibration bath is provided with a mixer to increase the circulation necessary for close temperature control. In the high temperature bath, the mixer must be turned off



91.572

Figure 4-19. — Temperature bath controller.

or removed from the molten salt before the salt temperature is reduced.

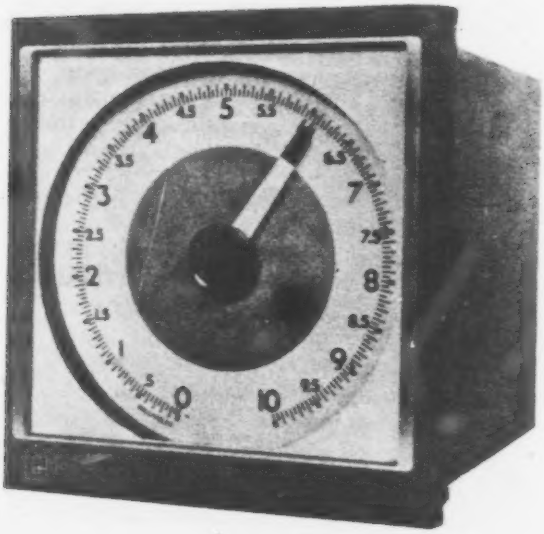
Each bath has a temperature controller, (fig. 4-19), located in the bottom of the cabinet. The control panel for the controller, (fig. 4-19), has a power on-off switch and coarse and fine temperature adjusting dials. Adjustment of coarse and fine temperature dials energizes the heaters and maintains the bath operating temperature. A pilot light indicates when the heaters are operating.

The resistance thermometer (Speedomax), (fig. 4-20), indicates temperatures by means of a pointer and circular scale. The calibration cycle of the Speedomax is 3 to 6 months in place with shop standards.

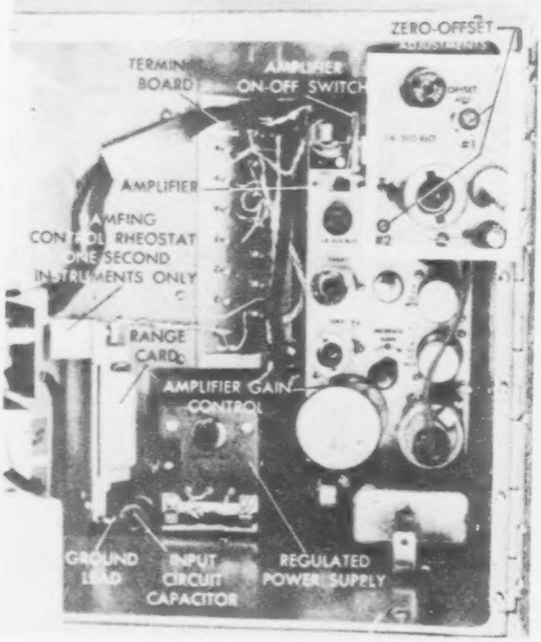
STARTING AND ADJUSTING THE SPEEDOMAX

STARTUP

To start the Speedomax, open the chassis and place the amplifier on-off switch, figure 4-21, in the ON position.


0
.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6.5
7
7.5
8
8.5
9
9.5
10

61.166.2(91C)
Figure 4-20.—Resistance thermometer temperature indicator.


ZERO-OFFSET ADJUSTMENTS
TERMINAL BOARD
AMPLIFIER ON-OFF SWITCH
OFFSET ADJ
#1
#2
AMPLIFIER
DAMPING CONTROL RHEOSTAT ONE SECOND INSTRUMENTS ONLY
RANGE CARD
AMPLIFIER GAIN CONTROL
GROUND LEAD
INPUT CIRCUIT CAPACITOR
REGULATED POWER SUPPLY

91.570
Figure 4-21.—Interior of case. Inset shows zero-offset adjustments.

ADJUST AMPLIFIER GAIN

After instrument startup and a warmup of at least two minutes with the instrument measuring the normal input signal, observe the instrument sensitivity. Then, if necessary, readjust the setting of the amplifier gain control knob, figure 4-21.

The optimum gain setting is that setting which gives maximum instrument sensitivity without causing "hunting"—that is, pointer oscillation. If oversensitivity, characterized by hunting, or insensitivity is noted, turn the amplifier gain control knob to its clockwise limit. Then turn the knob slowly counterclockwise until the hunting disappears or shows as only a slight quiver of the balancing motor worm.

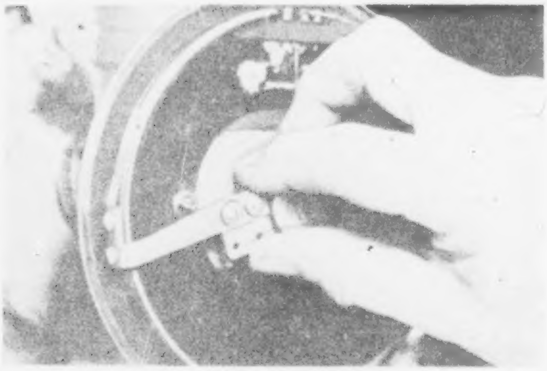
ADJUST DAMPING

Instruments having a step response time of 1.0 second (Model R round scale indicator) for full-scale changes of the measured variable are provided with a damping control rheostat, figure 4-21. There is a screwdriver adjustment located on the range card mounting bracket. After instrument startup and a warmup of at least two minutes with the instrument measuring the normal input signal, determine the proper setting of this rheostat as outlined in the following paragraph.

Manually rotate the slidewire contact arm, figure 4-22, to move the measuring pointer several inches from the balance point. Release the contact arm and observe the pointer behavior as the instrument balances. Turn the damping control rheostat counterclockwise until the pointer overshoots the balance point when this procedure is repeated. Then turn the rheostat clockwise until the overshoot just disappears. This setting of the damping control rheostat gives the smoothest and fastest balancing action.

ADJUST ZERO-OFFSET

Zero-offset adjustments have been set at the factory and ordinarily will not require initial readjustment. However, after a certain period of use, readjustment may be necessary. Refer to the manufacturer's technical manual when making this adjustment.



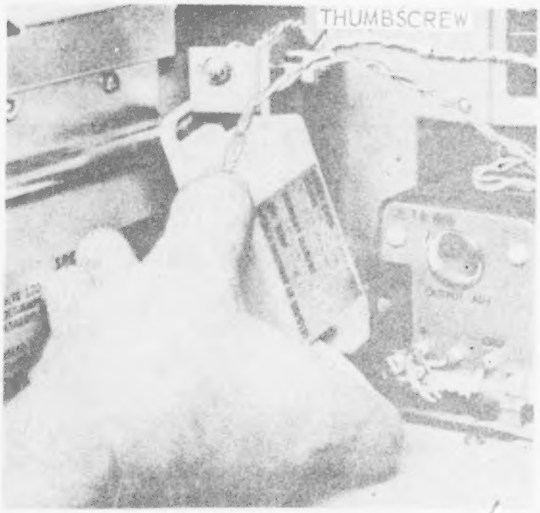
91.571
Figure 4-22.—Manual rotation of slidewire shaft.

AMPLIFIER GROUNDING

Upon completion of the foregoing steps, carefully observe the performance of the instrument. If sluggish operation, excessive dead band or erroneous readings are noted, the trouble may be caused by electrical interference entering the instrument amplifier. Quite often such interference can be readily eliminated by ungrounding the amplifier chassis and connecting it to the primary element circuit. Caution: Deenergize before changing connections. In particular, this procedure is effective whenever interference is due to (a) instrument case and primary element being at different ground potentials, or (b) primary element having an a-c or d-c potential with respect to ground.

RANGE CONVERSION

The Speedomax can be converted to a new range by replacing the range card (fig. 4-23) and scale. This is useful in calibration since to increase (expand) the scale over a given range, results in a more accurate scale reading. Increasing or decreasing scale does not change accuracy of instrument. However, scale readability is enhanced if span is decreased: a 0-500 scale is more readable than a 0-1000 scale. After a range change, calibration of the Speedomax should be rechecked as described later in chapter 5.



91.569
Figure 4-23.—Range card.

ADJUSTING THE TEMPERATURE CONTROLLER

It may be necessary to adjust the RESET and GAIN settings of the controller (fig. 4-19) as well as the temperature settings. The RESET and GAIN controls are located on the controller chassis. They can be reached by removing the mounting screws located in the extreme corners of the front panel, then withdrawing the controller from the bath housing. Once the control settings have been determined and made, they should not be changed unless the type of bath fluid (test medium) is changed or operating conditions of the bath are altered radically. (See chapter 5.)

OPERATING THE TEMPERATURE CONTROLLER

Any one of three modes of operation (on-off, proportional, and proportional with reset) may be used to control the temperature of the thermometer calibration bath with the temperature controller. A mode of operation is selected by positioning the reset switch. The reset switch, (fig. 4-19), has 10 positions. Positions 1 through 8 are for the proportional with reset mode, the

Table 4-2.—Sensitivity of Controller as a Proportional Controller

GAIN SWITCH POSITION	FRACTION OF MAX. GAIN	PROP. BAND TEMP. DIFF. 0 - 100% DUTY CYCLE	
		°F	°C
Off	0	-	-
1	1/256	10.6	5.888
2	1/128	5.31	2.944
3	1/64	2.65	1.472
4	1/32	1.32	0.736
5	1/16	0.663	0.368
6	1/8	0.331	0.184
7	1/4	0.165	0.092
8	1/2	0.083	0.046
9	1	0.041	0.023

91.573

9th position for the proportional mode, and the 10th position for the on-off mode.

Each of the first eight positions on the reset switch represents a reset rate of time, namely 6, 9, 13, 19, 27, 40, 60, or 90 seconds.

When the red pilot light on the control panel is on, depression of the quick-heat button will close the quick-heat relay and energize the quick-heat heaters. After the bath reaches the set temperature, the relay opens with the first "off" signal from the controller (indicated when the red pilot light goes off). The quick-heat heaters will remain off during the subsequent operation unless the quick-heat button switch is again depressed during an "on" period of the controller.

ON-OFF MODE

With the reset switch positioned for this mode, the wheatstone bridge in the controller is adjusted for a preselected temperature through the use of the coarse and fine temperature controls. As bath temperature varies, a relay is turned on and off by a control amplifier to control the current to the heaters, thus controlling the temperature.

PROPORTIONAL MODE

The proportional mode of operation is a function of the wheatstone bridge. A negative feedback signal unbalances the voltage to the bridge, producing an "on" period of the bath heater.

The controller proportions the heat output by time cycle modulations. Proper operation is indicated when the pilot light goes "on" and "off" regularly about once per second. This is known as the proportional band. Hunting occurs when the pilot light periodically increases and decreases its duty cycle or percentage of "on" time. This action is not to be confused with the on-off mode of operation.

The sensitivity of the controller as a proportional controller is determined by the position of the gain switch (fig. 4-21). The gain switch has an "off" and nine operative positions. Each operative position represents a fraction of the proportional-band, temperature-differential, 0-100% duty cycle. Refer to table 4-2.

PROPORTIONAL WITH RESET MODE

A positive feedback circuit, with an appropriate time constant is added to the negative feedback circuit to restore the bridge unbalance to zero. The time constant is determined by one of the eight positions of the reset switch.

On any proportional controller, maximum gain depends solely on the system being controlled. High gains result in hunting, or oscillations about the set point, while low gains produce a proportional offset due to change in load or heat demand of the system being controlled. In some systems, a relatively low gain must be used to avoid hunting. However, this gain may result in an unacceptable proportional offset, called droop. To overcome droop, the function of reset has been introduced in the controller. This function reduces the droop to about 1% of that present in the absence of reset.

MISCELLANEOUS TEMPERATURE CALIBRATION EQUIPMENT

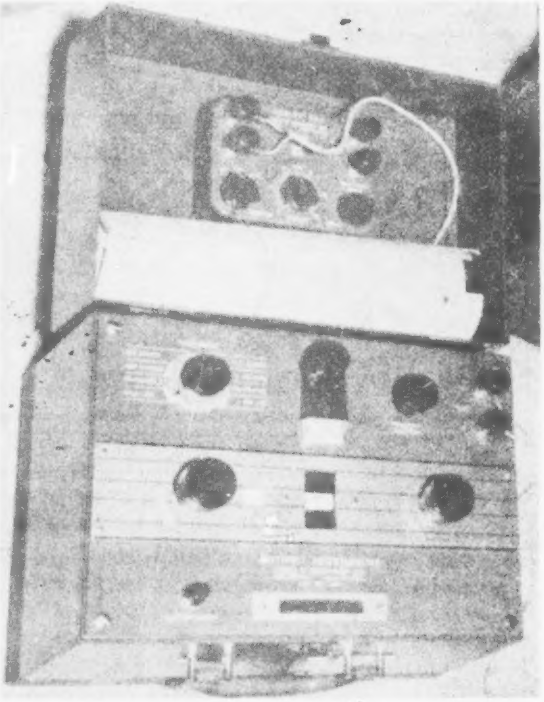
Other temperature calibration equipment used in conjunction with the temperature baths, Speedomax, or ASTM standards include a millivolt box, resistance thermometer bridge, and decade resistance box.

MILLIVOLT BOX

The millivolt box, (fig. 4-24), is used to measure the electromotive force produced by thermocouples. The range of the millivolt box is -11.0 millivolts to +101.0 millivolts. It is a portable potentiometer that contains an unsaturated standard voltage cell, a working voltage source (battery), a galvanometer, a resistance network, and all necessary switches. The required calibration cycle for the millivolt box is 12 months.

Highly accurate voltage measurements are made using the potentiometer which compares an unknown voltage to a known, or reference, voltage. The standard cell is a stable voltage reference that must not be used as a battery. Doing so upsets the chemical balance and may destroy the cell or at least alter the reference voltage. The cell is not designed to have a current drawn from it.

The potentiometer compares an unknown voltage to the standard cell voltage without drawing any significant current from the cell or the source being measured. At the balance or measuring point there is no current drain from the cell or the unknown voltage source.



61.168.1
Figure 4-24.—Millivolt potentiometer.

In voltage measurements, the battery drives a standardized current through a known resistance. The product of this current and the resistance between any two points along the resistance string is an accurately known voltage. The resistors are selected so that when a standardized current flows through them, each setting of the variable resistor (slide wire) corresponds to a voltage output. A table is then used to convert voltage to temperature.

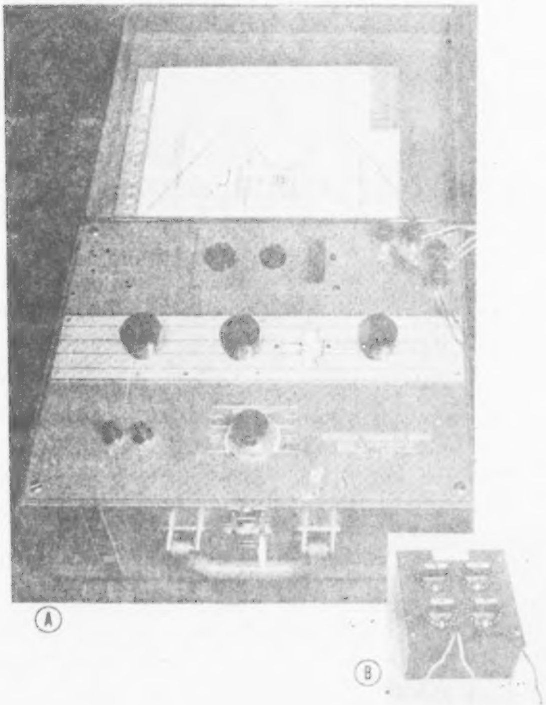
Figure 4-25 is a table that gives the expected millivolt output for a specific type of thermocouple with the hot junction temperature given in °C. This table provides temperature values corresponding to the nearest hundredth of a millivolt.

(Electromotive Force in Absolute Millivolts. Temperatures in Degrees C (Int. 1948). Reference Junctions at 0° C.)

Millivolts	.000	.010	.020	.030	.040	.050	.060	.070	.080	.090	.100	Millivolts
	Degrees C											
0.000	0.0	1.8	3.6	5.4	7.2	9.0	10.7	12.5	14.3	16.0	17.7	0.000
.100	17.7	19.4	21.1	22.8	24.5	26.2	27.8	29.5	31.1	32.8	34.4	.100
.200	34.4	36.0	37.6	39.2	40.8	42.4	44.0	45.6	47.1	48.7	50.2	.200
.300	50.2	51.8	53.3	54.8	56.4	57.9	59.4	60.9	62.4	63.9	65.4	.300
.400	65.4	66.9	68.3	69.8	71.3	72.7	74.2	75.6	77.1	78.5	79.9	.400
.500	79.9	81.4	82.8	84.2	85.6	87.0	88.5	89.9	91.3	92.7	94.0	.500
.600	94.0	95.4	96.8	98.2	99.6	100.9	102.3	103.7	105.0	106.4	107.7	.600
.700	107.7	109.1	110.4	111.8	113.1	114.4	115.8	117.1	118.4	119.7	121.0	.700
.800	121.0	122.4	123.7	125.0	126.3	127.6	128.9	130.2	131.5	132.8	134.1	.800
.900	134.1	135.3	136.6	137.9	139.2	140.5	141.7	143.0	144.3	145.5	146.8	.900
1.000	146.8	148.1	149.3	150.6	151.8	153.1	154.3	155.6	156.8	158.1	159.3	1.000
1.100	159.3	160.6	161.8	163.0	164.3	165.5	166.7	167.9	169.2	170.4	171.6	1.100
1.200	171.6	172.8	174.1	175.3	176.5	177.7	178.9	180.1	181.3	182.5	183.7	1.200
1.300	183.7	184.9	186.1	187.3	188.5	189.7	190.9	192.1	193.3	194.5	195.7	1.300
1.400	195.7	196.9	198.1	199.2	200.4	201.6	202.8	204.0	205.2	206.3	207.5	1.400
1.500	207.5	208.7	209.9	211.0	212.2	213.4	214.5	215.7	216.9	218.0	219.2	1.500
1.600	219.2	220.4	221.5	222.7	223.8	225.0	226.2	227.3	228.5	229.6	230.8	1.600
1.700	230.8	232.0	233.1	234.3	235.4	236.6	237.7	238.9	240.0	241.1	242.3	1.700
1.800	242.3	243.4	244.6	245.7	246.9	248.0	249.1	250.3	251.4	252.5	253.7	1.800
1.900	253.7	254.8	255.9	257.1	258.2	259.3	260.4	261.5	262.7	263.8	264.9	1.900
2.000	264.9	266.1	267.2	268.3	269.4	270.5	271.7	272.8	273.9	275.0	276.1	2.000
2.100	276.1	277.2	278.4	279.5	280.6	281.7	282.8	283.9	285.0	286.1	287.2	2.100
2.200	287.2	288.3	289.4	290.5	291.6	292.7	293.8	294.9	296.0	297.1	298.2	2.200
2.300	298.2	299.3	300.4	301.5	302.6	303.7	304.8	305.9	307.0	308.1	309.2	2.300
2.400	309.2	310.3	311.4	312.5	313.5	314.6	315.7	316.8	317.9	319.0	320.1	2.400
2.500	320.1	321.2	322.2	323.3	324.4	325.5	326.6	327.6	328.7	329.8	330.9	2.500
2.600	330.9	331.9	333.0	334.1	335.2	336.3	337.3	338.4	339.5	340.6	341.6	2.600
2.700	341.6	342.7	343.8	344.8	345.9	347.0	348.1	349.1	350.2	351.3	352.3	2.700
2.800	352.3	353.4	354.5	355.5	356.6	357.7	358.7	359.8	360.8	361.9	363.0	2.800
2.900	363.0	364.0	365.1	366.2	367.2	368.3	369.3	370.4	371.5	372.5	373.6	2.900
3.000	373.6	374.6	375.7	376.7	377.8	378.9	379.9	381.0	382.0	383.1	384.1	3.000
3.100	384.1	385.2	386.2	387.3	388.3	389.4	390.4	391.5	392.5	393.6	394.6	3.100
3.200	394.6	395.7	396.7	397.8	398.8	399.9	400.9	402.0	403.0	404.1	405.1	3.200
3.300	405.1	406.2	407.2	408.3	409.3	410.4	411.4	412.4	413.5	414.5	415.6	3.300
3.400	415.6	416.6	417.7	418.7	419.8	420.8	421.8	422.9	423.9	425.0	426.0	3.400
3.500	426.0	427.0	428.1	429.1	430.2	431.2	432.2	433.3	434.3	435.3	436.4	3.500
3.600	436.4	437.4	438.5	439.5	440.5	441.6	442.6	443.6	444.7	445.7	446.7	3.600
3.700	446.7	447.8	448.8	449.8	450.9	451.9	452.9	453.9	455.0	456.0	457.0	3.700
3.800	457.0	458.1	459.1	460.1	461.1	462.2	463.2	464.2	465.3	466.3	467.3	3.800
3.900	467.3	468.3	469.4	470.4	471.4	472.4	473.5	474.5	475.5	476.5	477.5	3.900
4.000	477.5	478.6	479.6	480.6	481.6	482.6	483.7	484.7	485.7	486.7	487.7	4.000
Millivolts	.000	.010	.020	.030	.040	.050	.060	.070	.080	.090	.100	Millivolts

91.574

Figure 4-25.—Platinum vs platinum/10% rhodium thermocouple table (partial).



61.167

Figure 4-26.—Resistance thermometer equipment. (A) Resistance thermometer bridge; (B) Resistance box.

RESISTANCE THERMOMETER BRIDGE

The resistance thermometer bridge, (fig. 4-26A), is a double slide-wire wheatstone bridge used to calibrate resistance thermometers. The bridge measures the resistance of a three- or four-lead resistance thermometer over the range of 0 to 160.1 ohms. Since each resistance thermometer has a known specific resistance-versus-temperature characteristic, the resistance measurement can be converted to its temperature value by means of a table such as figure 4-27.

	Temperature (°C)	Resistance Ratio	Inverse Difference
	0	1.000000	-
	1	1.003984	251.03
	2	1.007966	251.10
	3	1.011947	251.18
	4	1.015927	251.25
R_0 = 25.5540 Ω	5	1.019906	251.33
	6	1.023884	251.40
	7	1.027861	251.47
	8	1.031836	251.55
	9	1.035810	251.62
	10	1.039783	251.70
	11	1.043755	251.77
	12	1.047726	251.84
	13	1.051695	251.92
	14	1.055664	251.99
	15	1.059631	252.07

91.575

Figure 4-27.—Typical platinum resistance thermometer table (partial).

DECADE RESISTANCE BOX

The decade resistance box, (fig. 4-26B), is for general use in circuits, such as those in the resistance thermometer bridge, where an error of 0.1% is acceptable. The decade resistance box consists of an assembly of precision resistors whose individual values are in submultiples and multiples of ten. Each section contains ten equal value components connected in series. The total value of each section is ten times that of the preceding section. By setting the 10-position selector switch in each section, the decade box can be set to any desired value within its range. The range of the resistance box is 0 to 999.9 ohms.

CHAPTER 5

INSTRUMENT CALIBRATION PROCEDURES

Calibration procedures describe operations required to calibrate instruments. As an Instrumentman First Class or Chief, you should be able to identify the procedures pertaining to equipment in MIRCS, perform calibrations with the help of these procedures, and direct your men to calibrate instruments accurately and safely. Even though there are no approved calibration procedures prepared specifically for use in MIRCS, some procedures are referred to as MIRCS procedures.

The proposed NAVSHIPS manual No. 391-1320, MIRCS for Tenders and Repair Ships, a standardization report of 30 April 1967, lists various procedures and publications applicable to MIRCS operation.

The Metrology Requirements List, NAVAIR 17-35 MTL-1, lists authoritative reference documents which contain data applicable to the calibration or qualification of test and measuring equipment. The documents are listed by 5-digit manufacturers' codes, which are derived from the Defense Supply Agency Handbook, H-4 series. The documents contain, for a particular piece of test and measuring equipment, the following: type designation, manufacturer's number, item name or federal stock number, cycle of calibration, maintenance manual or supplemental data, and approved calibration procedure, if any.

Most procedures given in these documents were developed for Calibration Laboratories, and do not apply directly to MIRCS; the laboratories and equipped with the calibration equipment mentioned in the procedures, whereas MIRCS are not. Remember, the procedures are useful as guidelines as are the references found in them.

The Metrology Engineering Center Publications Index contains a list of all current calibration procedures. This index is published quarterly and is a handy reference for checking the most current procedure. An asterisk (*) preceding the issue date number indicates that the procedure has been changed since the original publication date.

A special letter-number system is used to identify the Instrument Calibration Procedure (ICP). Take for example, NAVAIR 17-20MP-01. The numbers 17-20 identify the procedure as an official NAVAIR publication. The letters MP identify the general area and function of the applicable test instrument. The number 01 is the serial number of the procedure. Letters in this system are assigned as indicated by the chart of figure 5-1. Either two digits or three digits make up the serial numbers of ICPs in each area or function group. The NAVAIR prefix on new and reissued documents replaces the former NAVWEPS prefix. The two prefixes are equivalent.

Local Calibration Procedures (LCPs) are used to expedite calibration information to the field laboratories. LCPs are developed by various Navy activities and consist of material extracted (with appropriate changes) from maintenance manuals, handbooks, manufacturers' literature, and other calibration procedures. LCPs do not necessarily comply with MIRCS format requirements, but provide adequate technical information. LCPs must be approved by MEC before they can be used as reference in the calibration program.

If a calibration procedure for an item of equipment is not listed in the Metrology Requirements List or the Metrology Engineering Center Publications Index, refer to the manufacturer's handbook or maintenance manual or to other sources, such as NAVSHIPS manuals.

TORQUE TESTERS

Each torque tester, regardless of range or size, must be calibrated at least every 6 months and adjusted as necessary to verify that it may be used to calibrate torque wrenches. Generally a precision torque is generated and applied to

ELECTRO-ELECTRONIC	MICROWAVE	MECHANICAL	ELECTRO-MECHANICAL	QUALIFICATION
First Letter:				
A - ICP B - MSOP C - CCP D - ICT	G - ICP H - MSOP I - CCP J - ICT K - MSOT	M - ICP N - MSOP O - CCP P - ICT	S - ICP T - ICT	V - Phases A & C W - Phase C-1 X - Phases B & D
Second Letter:				
A Active Network	A Attenuation	A Angular Rot.	A Acoustical	A Active Network or Attenuation
B	B	B	B	B
C Capacitance	C	C Chemical	C	C
D Detectors and Galvanometers	D Detecting	D Dimensional	D	D
E EMF, Voltage	E	E	E	E EMF, Voltage
F Frequency & Time	F Frequency	F Force	F Dynamic Force	F Frequency & Time
G Sig. Generators	G Sig. Generators	Fluid Flow	G	G Sig. Generators
H Power Supplies	H Power Supplies	H Humidity	H	H Power Supplies
I Current	I	I	I Infrared	I Current
J	J	J	J	J
K	K	Kinematic	K	K
L Inductance	L	L Optics	L Light	L
M Magnetic	M	M Mass	M	M
N Passive Network	N Passive Network	N Metallurgy	N	N Passive Network
O	O	O	O	O
P Power and Energy	P Power	P Pressure	P Dynamic Press.	P Power or Pressure
Q Multifunction	A Multifunction	A Multifunction	A Multifunction	
R Resistance	R	R Radiation	R Radiation	R Resistance
S Field Strength	S Phase Shifting	S Sp. Gr. & Dens.	S	S
T	T	T Temperature	T Temperature	T
U	U	U Torque & Power	U	U
V	V VSWR	V Viscosity	V Vib. & Accel.	V Power factor
W Wave Analyzers	W Wave Analyzers	W Volume	W	W Wave Analyzers
X Special Equip.	S Special Equip.	X Special Equip.	X Special Equip.	X Special Equip.
Y Tube/Transistor Testers	Y Miscellaneous	Y Miscellaneous	Y Miscellaneous	Y
Z Impedance, SWR	Z	Z	Z	Z

Last two or three digits are the procedure serial number

91.577

Figure 5-1.—Procedure numbering system.

the tester, and the reading of the tester is compared to the known torque.

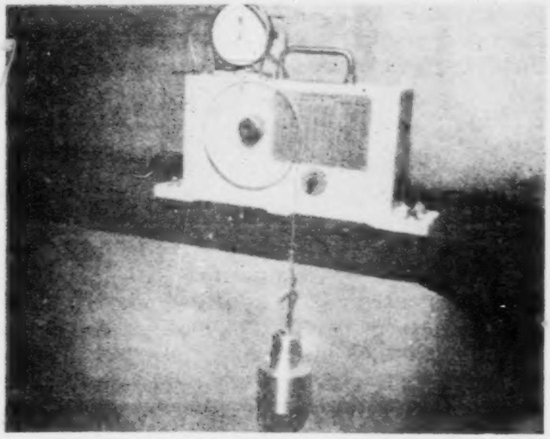
BASIC PRINCIPLES

One method of developing a precise torque is to use a known moment arm and deadweights. An arm and a series of weights, which will cover the span of the tester to be calibrated, are chosen and the weights are loaded on the arm at a known distance in sequence to generate different values of torque. A torque tester under calibration is illustrated in figure 5-2.

A disc of known radius is attached to the input shaft of the tester. As weight is added, the disc rotates slightly and the torque generated increases according to the formula L = Wr, where L is torque, W is weight, and r is radius. As the disc rotates, the point of tangency between the weight holder and disc also changes. It is at this point that the weight acts to generate torque. Thus, the weight always acts perpendicular to the radius and no error results due to the rotation of the disc.

If a tester had a range of 0 to 100 lb-in., the disc used might have a radius of 10 inches. Ten weights of one pound each would allow the operator to generate a total torque of 100 lb-in., with 10 lb-in. increments.

The basic disc configuration becomes impractical for calibrating high range testers since weight restrictions may require that the radius of the moment arm be several feet. In this case, ah arm is used which represents only a section



91.578
Figure 5-2.—Torque tester calibration.

of a disc, (fig. 5-3), whose radius arms, r_1 and r_2, are equal. The system is statically balanced with a counterweight to ensure that the arm itself does not generate any torque. The arc on the arm is long enough so that under full load the weights W are tangent to some part of the arc on the arm. Thus, regardless of the arm position, the torque L imposed on the tester equals weight times radius arm. Again, the formula is L = Wr.

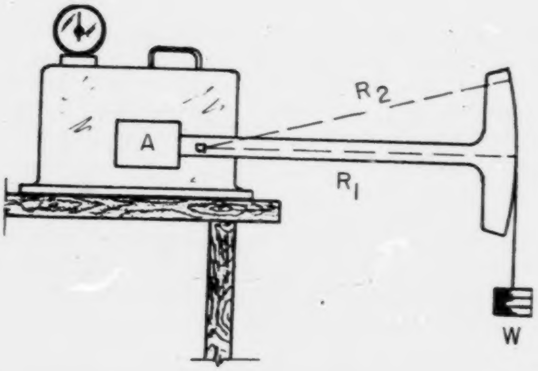


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Figure 5-3.—High torque calibration arm.

Calibration systems which use a known moment arm and deadweight are usually accurate to ±0.01% of INDICATED TORQUE.

One question which generally arises in torque tester calibration using deadweights concerns gravity. The weights used for calibration are reasonably precise; usually, the nominal weight is generally stamped on each. Since this weight is the weight at 45° N latitude and sea level, the torque generated at any other latitude and altitude should be corrected. The correction factor L_a is determined by the formula:

$$L_a = W \times r \times \frac{g}{g_0}$$

where $\frac{g}{g_0}$ = the ratio of local gravity to standard gravity,

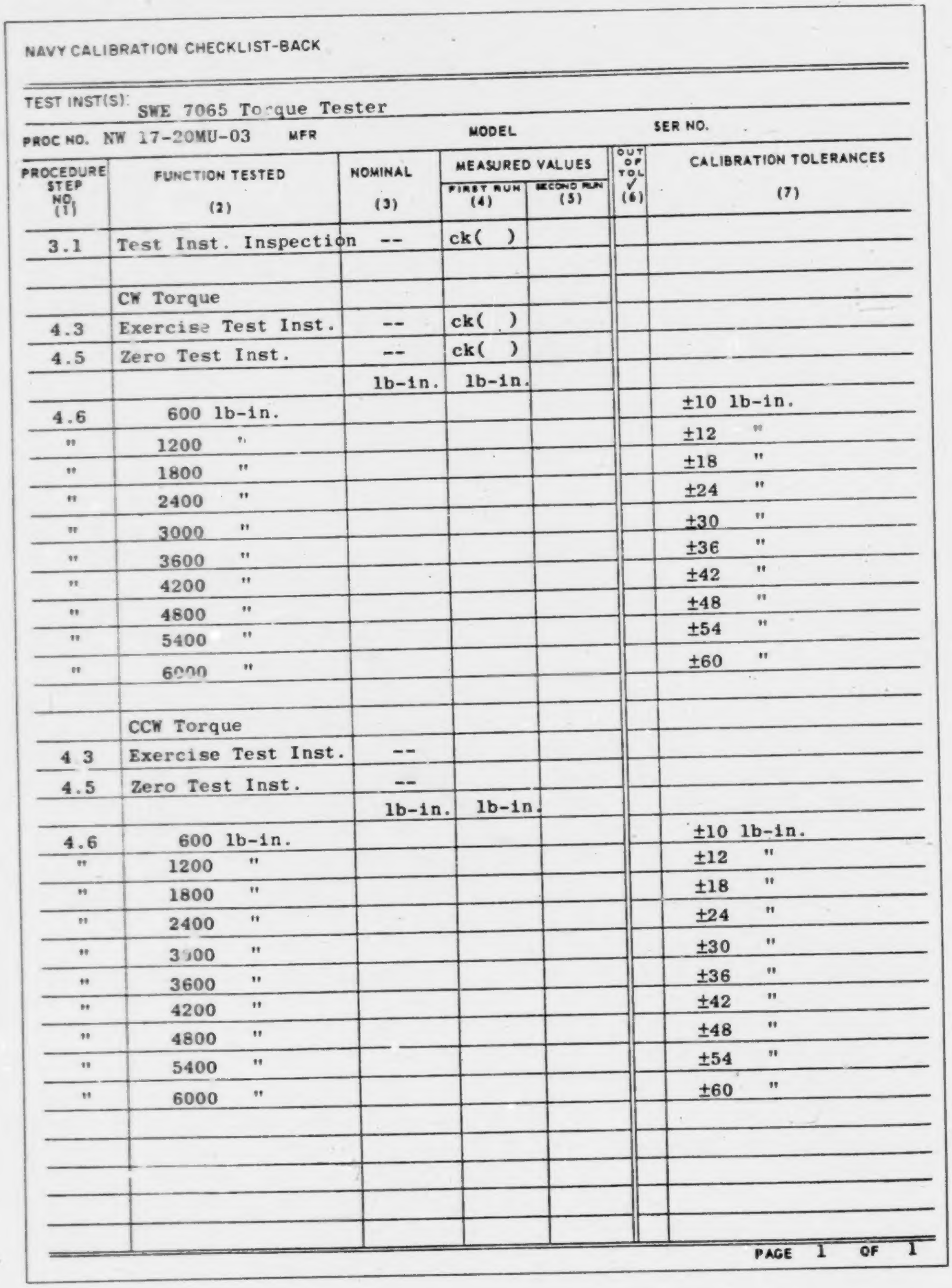
W = nominal weight, and

r = length of radius arm.

Actually, the value of local gravity (and thus, weight,) varies approximately ±0.2% from standard gravity between the North and South Poles and the Equator. If the tester being calibrated had a tolerance of ±1%, then the maximum error introduced by not making a gravitational correction to the weights would be 1/5 of the tester tolerance, and this magnitude only if the tester were being calibrated at one of the Poles or at the Equator. In most laboratories, the error introduced would be far less. Thus, the gravitational correction can be omitted in most torque tester calibrations. But where the tester is more precise than ±1%, the gravitational correction should be considered to determine whether or not it is a significant source of error in the calibration.

CALIBRATION OF TORQUE TESTERS

NAVAIR 17-20MU-03 describes the procedure for calibrating flexible-beam and torsion-bar torque testers within the range of 5 oz-in. to 1000 lb-ft. This procedure requires that the standards carry evidence of current calibration and that a checklist (fig. 5-4) be used to record all calibration data. The checklist refers to the torque tester being calibrated as the test instrument. The procedure step numbers in column 1 of the checklist correspond to those in NAVAIR 17-20MU-03. Ten points equally spaced



NAVY CALIBRATION CHECKLIST-BACK

TEST INST(S): SWE 7065 Torque Tester

PROC NO. NW 17-20MU-03 MFR MODEL SER NO.

PROCEDURE STEP NO.	FUNCTION TESTED	NOMINAL	MEASURED VALUES		OUT OF TOL ✓	CALIBRATION TOLERANCES
(1)	(2)	(3)	FIRST RUN (4)	SECOND RUN (5)	(6)	(7)
3.1	Test Inst. Inspection	--	ck( )			
	CW Torque					
4.3	Exercise Test Inst.	--	ck( )			
4.5	Zero Test Inst.	--	ck( )			
		lb-in.	lb-in.			
4.6	600 lb-in.					±10 lb-in.
"	1200 "					±12 "
"	1800 "					±18 "
"	2400 "					±24 "
"	3000 "					±30 "
"	3600 "					±36 "
"	4200 "					±42 "
"	4800 "					±48 "
"	5400 "					±54 "
"	6000 "					±60 "
	CCW Torque					
4 3	Exercise Test Inst.	--				
4.5	Zero Test Inst.	--				
		lb-in.	lb-in.			
4.6	600 lb-in.					±10 lb-in.
"	1200 "					±12 "
"	1800 "					±18 "
"	2400 "					±24 "
"	3000 "					±30 "
"	3600 "					±36 "
"	4200 "					±42 "
"	4800 "					±48 "
"	5400 "					±54 "
"	6000 "					±60 "

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91.580

Figure 5-4.—Navy calibration checklist-back.

throughout the range of the test instrument are selected and recorded on the checklist.

Preliminary Operations

Before the torque tester is calibrated, the following steps are taken:

1. Verify that the test instrument is clean and free of defects that would obviously impair its operation.
2. Record the values listed in column 2 (fig. 5-4) on the checklist as the NORMAL values for the calibration points, if the correction for local gravity (g/g_o) is within the limits 0.9985 and 1.0015; if not, compute the nominal values by means of the formula:

$$\text{Nominal value} = (\text{value in col 2}) \ \text{X} \ g/g_o$$
$$= \frac{\text{local gravity in gals}}{980.665 \text{ gals}}$$

The gal, a unit of acceleration, is equivalent to one centimeter per second per second (cm/sec^2). If the local gravity factor is unknown, determine its approximate value from figure 5-5.

Calibration Procedure

Mount the test instrument on a rigid work surface so that the torque standard can be attached to the input shaft to apply clockwise (cw) torque, and so that the arc of the lever will be vertical, and the lever and weight will be unobstructed when the torque standard lever is placed on the shaft and the weight is suspended from the lever. If the test instrument is designed to measure torque greater than 500 oz-in., secure the test instrument to the work surface.

Place the appropriate lever arm (or wheel) on the test instrument shaft for application of cw torque.

If the test instrument is a torsion-bar type, exercise it as follows:

1. Place the appropriate weight holder and sufficient weights on the lever arm cable to obtain a test instrument full-scale indication.
2. After one minute, remove the torque by raising (or removing) the weights.
3. Reapply the torque by lowering (or replacing) the weights.
4. Repeat steps 2 and 3 above four more times.

If applicable, remove the weight holder from the lever arm.

Zero the test instrument in accordance with the manufacturer's instructions. NOTE: If the lever arm is an unbalanced type, remove it before you zero adjust.

Measure as follows at each cw torque calibration point on the checklist:

1. Place the weight holder and the appropriate weights on the lever arm to apply to nominal value of torque.
2. Decrease the torque slightly, set the test instrument pointer to some value less than the nominal value, carefully increase the torque so that the pointer moves slowly up scale until the full torque is applied, then note the test instrument indication. Repeat this step until consistent results are obtained. Excessive shock or vibration in the work area may cause erratic torque indications during static torque measurements. If necessary, select another work area or perform the test when such forces are absent.

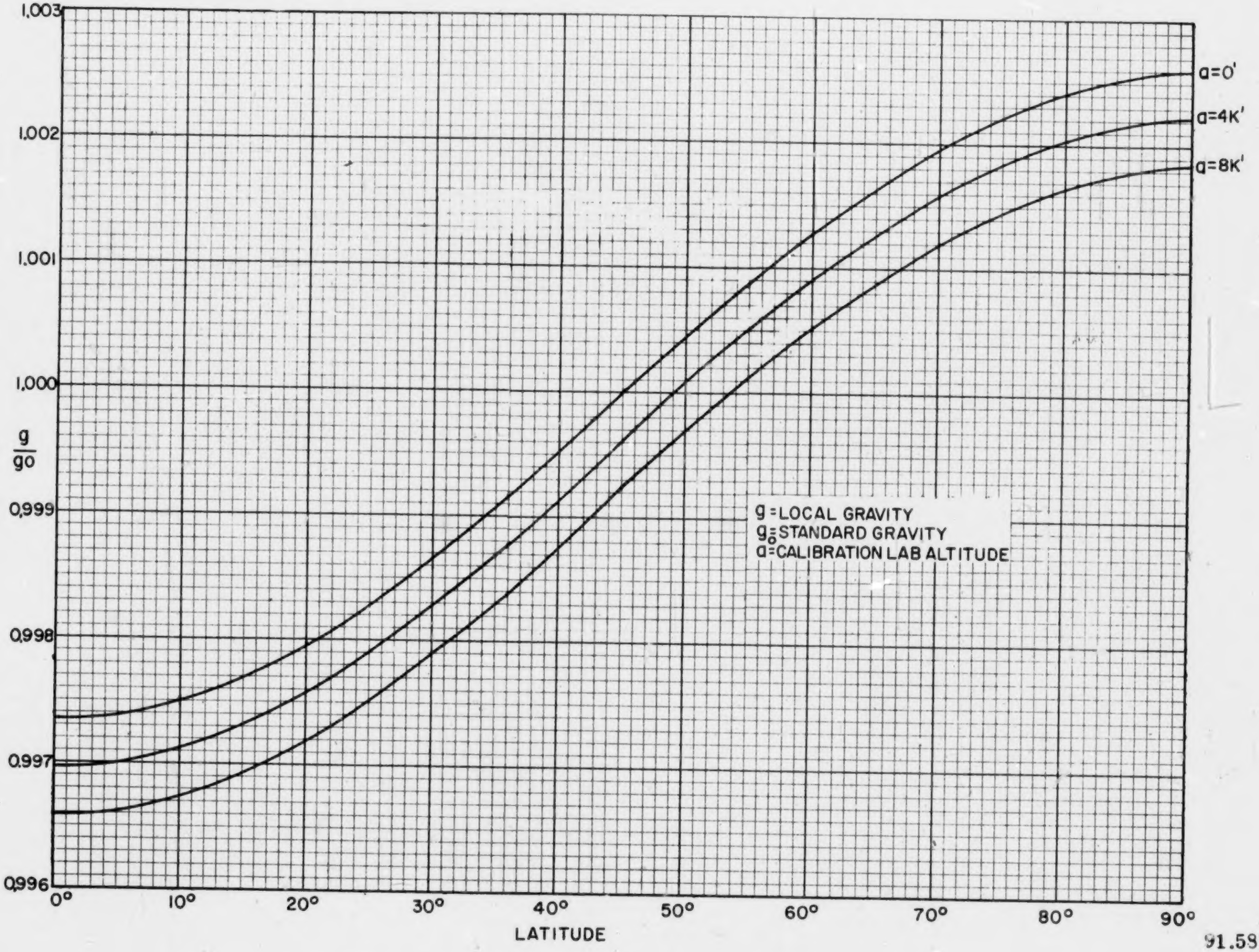
NOTE: For test instruments having a memory-type indicator, carefully press the weight or arm upward, resetting the pointer, then slowly removing the upward pressure. This must be accomplished so as to avoid dropping or swinging the weight. On the Torque Controls ET series testers, it may be sufficient to press the reset shaft (to decrease the pressure and reset the pointer), then slowly release the reset shaft.

3. Repeat the preceding step two more times, compute the average of the values noted, then verify that the result in within the acceptable limits for the calibration point.

If the test instrument is designed to measure counterclockwise (ccw) torque, repeat steps 1 through 3, applying torque in the ccw direction.

Verify that the test instrument is in acceptable condition; if not, take corrective action and repeat the applicable steps. The corrective action is described in chapter 11 of Instrumentman 3 & 2, NAVPERS 10193-C.

Unless other measurements are to be performed, secure the equipment in accordance with local laboratory practice.



91.581

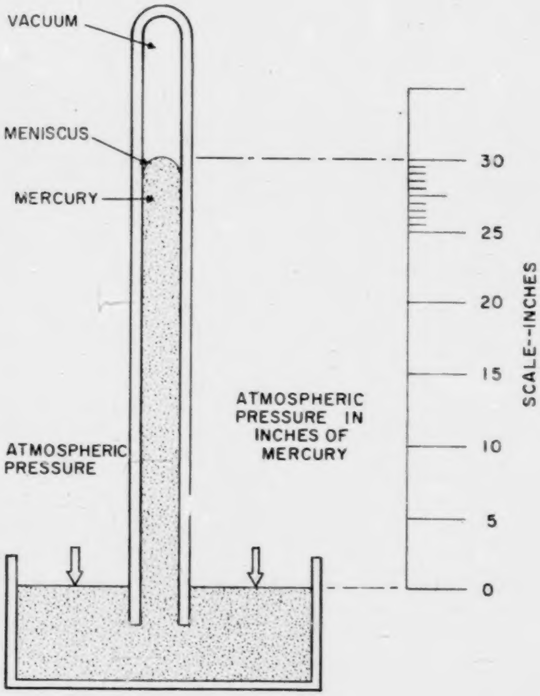
Figure 5-5.—Gravity correction factor vs latitude and elevation.

BAROMETERS

The barometer is an absolute pressure device made especially to measure atmospheric pressure. Two kinds are used by the Navy; mercury and aneroid.

CONSTRUCTION FEATURES

In its basic form the mercury barometer is made of a long glass tube sealed at one end and filled with mercury. Then open end is submerged in a container of mercury. The mercury in the tube settles, leaving a vacuum above it. As shown in figure 5-6, atmospheric pressure is indicated by the height of mercury in the tube above the level of mercury in the container. Atmospheric pressure is usually measured or indicated in inches of mercury or millibars. Figure 5-7 shows the relationships among the common pressure measuring units.



69.86(147B)
Figure 5-6. — Atmospheric pressure.

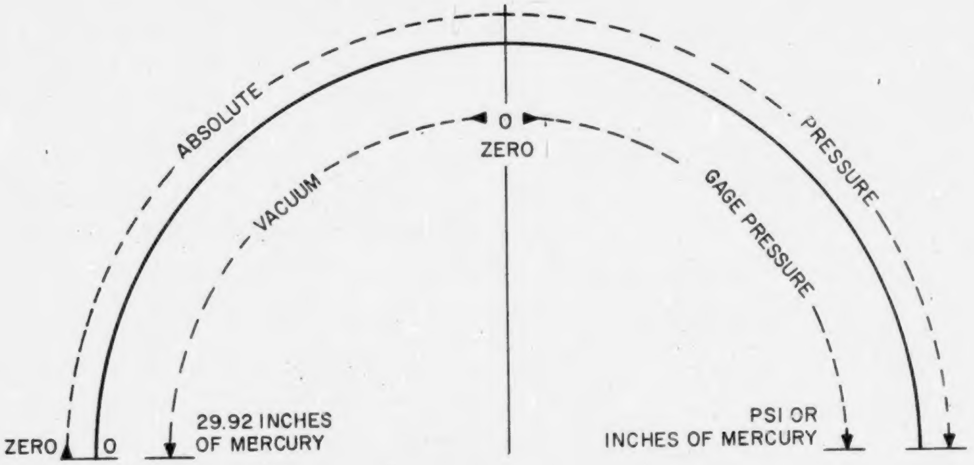
An aneroid barometer consists of an evacuated capsule linked to a pointer which indicates the atmospheric pressure directly on a dial scale. Its principal part is the evacuated pressure capsule or cell which is usually a diaphragm assembly, — a flexible walled, sealed metal chamber containing a partial vacuum or (in some) a total vacuum. One wall of the chamber is secured to the frame of the instrument as in figure 5-8 and 5-9. The free wall of the chamber is connected by a combination of levers, sector racks, pinions, pivots, or linkage chains to the indicator hand. Any change in atmospheric pressure will cause the diaphragm wall to move. An increase in atmospheric pressure compresses the chamber. When pressure falls, the chamber expands. Movement of the diaphragm wall causes the pointer to turn, and atmospheric pressure can be read directly on the dial.

Refering to figures 5-8 and 5-9 you may see the difference between the two types of aneroid barometers used in the Navy. The Taylor barometer which has a single diaphragm whereas the Fritz barometer has a dual diaphragm.

CALIBRATION OF ANEROID BAROMETERS

Calibrating an aneroid barometer involves reading the atmospheric pressure on a master mercury barometer (one of known accuracy) and setting the pointer of the aneroid barometer to indicate the reading exactly. If the pointer has to be moved a short distance to indicate the true reading, try turning the zero adjust screw (figs. 5-8 and 5-9). In case this screw does not move the pointer far enough, lift the pointer off and reset it, using a pointer puller.

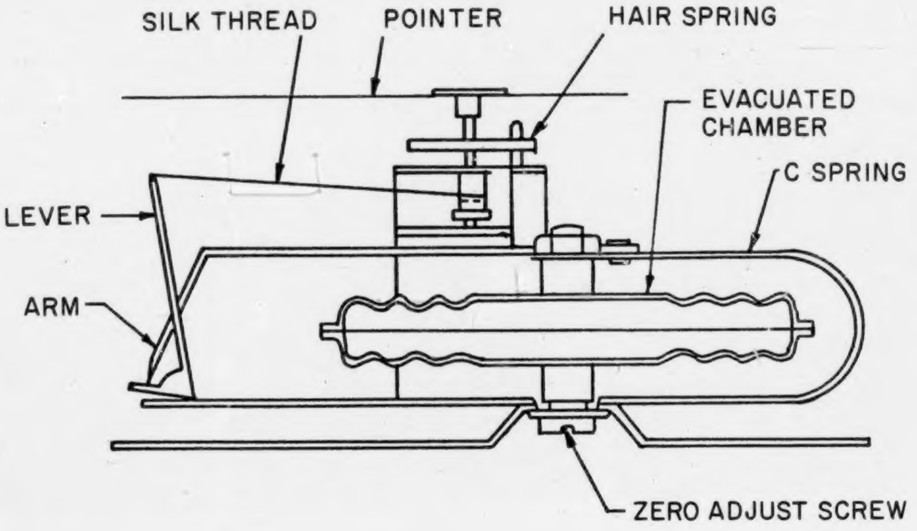
Next, place the barometer in a pressure or vacuum chamber (bell jar) with a master barometer. If a master barometer is not available, use a mercury column or manometer connected to the test chamber. Compare the readings of the aneroid barometer and master barometer throughout the range of the test instrument dial. Differences in compared readings indicate that the test instrument needs adjustment.


ABSOLUTE
PRESSURE
0
ZERO
VACUUM
GAGE PRESSURE
ZERO
0
29.92 INCHES OF MERCURY
PSI OR INCHES OF MERCURY

PSIG	PSIA	IN HG ABS	MM HG ABS OR TORR	MILLIBARS	IN H_2O ABS	STANDARD ATMOSPHERE	MICRONS HG ABS
0	14.7	29.92	760	1013.3	406.912	1	760,000

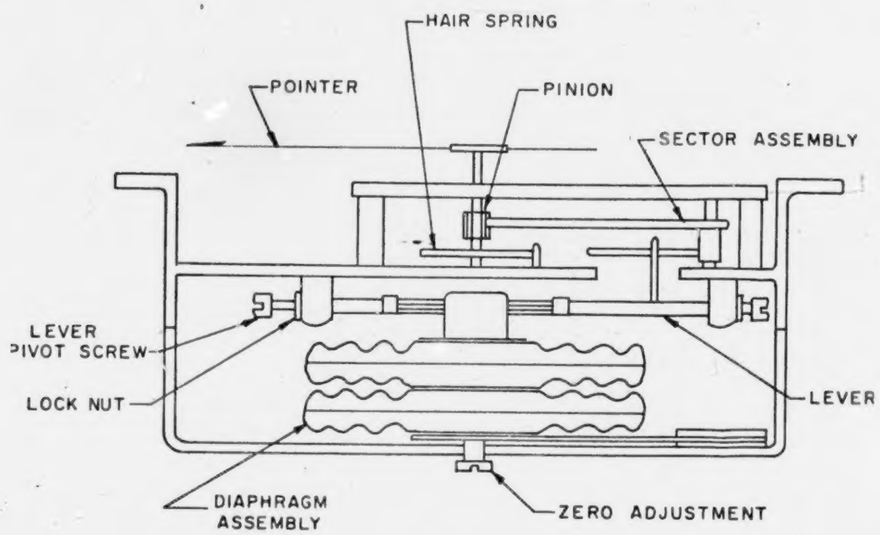
139.8

Figure 5-7.—Relationship of gage pressures and other units of pressure measurement (read in).


SILK THREAD
POINTER
HAIR SPRING
EVACUATED CHAMBER
C SPRING
LEVER
ARM
ZERO ADJUST SCREW

69.87(91C)A

Figure 5-8.—Taylor type aneroid barometer.


HAIR SPRING
POINTER
PINION
SECTOR ASSEMBLY
LEVER PIVOT SCREW
LOCK NUT
LEVER
DIAPHRAGM ASSEMBLY
ZERO ADJUSTMENT

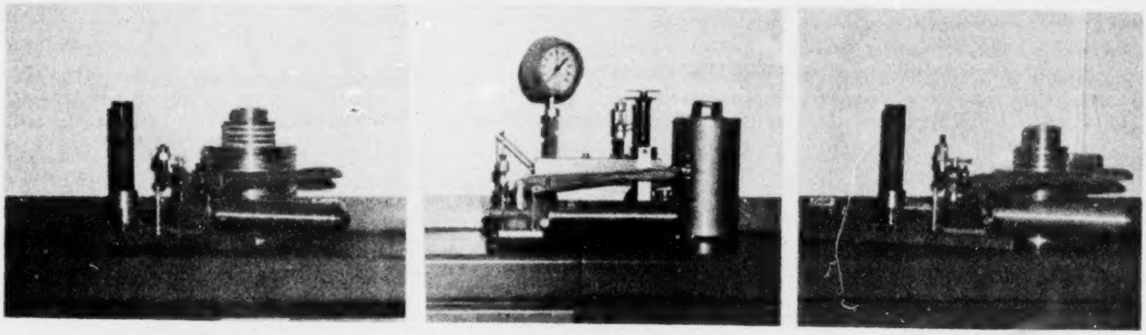
69.87(91C)B

Figure 5-9. — Friez type aneroid barometer.

USING DEADWEIGHT TESTERS AS REFERENCE STANDARDS

The Mansfield and Green, model T-130 (water r oil) or Amthor, model 472, bifluid dead-eight tester, figure 5-10, is used in the calibration of pressure working standards. Both testers re installed in MIRCS. In the procedure for alibrating a bourdon tube pressure gage, a nown pressure is applied to the gage by means of a hydraulic system and deadweights, and the known pressure is compared with the pressure gage indications.

Calibrated weights are placed on the piston and the pump increases the hydraulic pressure until the piston floats. The piston is rotated to reduce friction and the hydraulic pressure is indicated on the pressure gage under test. This procedure should serve as a guideline


OIL
BIFLUID
WATER

54.142

Figure 5-10. — Dead weight testers.

in the calibration of any gage requiring an accuracy greater than that provided by test panels.

CALIBRATION OF BOURDON TUBE PRESSURE GAGES

NAVAIR 17-20MP-01 describes the procedure for calibrating bourdon tube pressure gages with accuracies from 0.1% to 0.5%, and within the range of 0 to 10,000 psig. The operator should read the entire procedure before starting the calibration. This procedure requires that standards carry evidence of current calibration and that the calibration data be recorded on the CHECKLIST.

The test instrument indication is compared to the known pressure at selected nominal values throughout the range of the test instrument to determine whether or not it is within the required tolerance. Adjustment and maintenance is performed in accordance with the manufacturer's instruction manual or local MIRCS practices.

Preliminary Operations

Inspect the test instrument for cleanliness, damage, mechanical interference, bent pointer, and other defects. Repair obvious defects at this time, and clean the test instrument, as required.

Zero the test instrument if required.

Verify that the deadweight tester is clean, level, filled with clean fluid and purged of all air. All its valves must be closed, and all fittings leaktight.

Allow the test instrument and deadweight tester at least 24 hours to reach the ambient temperature of MIRCS before starting calibration. Make sure the temperature within MIRCS is 72° F ±5° F to eliminate having to apply a temperature correction.

Calibration Procedure

Using required fittings, connect the test instrument in an upright position to the appropriate deadweight tester. If possible, connect the bourdon tube at the same height as the bottom of the deadweight piston to eliminate having to apply a head correction. Before connecting the test instrument, also make certain that the fluid is at the HIGHEST point in the fitting at the connection.

INITIAL ADJUSTMENTS.—Before proceeding, post a DANGER HIGH PRESSURE SIGN AT THE WORK AREA. THIS PROCEDURE INVOLVES PRESSURES THAT ARE HAZARDOUS TO PERSONNEL. Wear safety glasses and steel toe stafety shoes.

With the hand pump, apply pressure, to the test instrument and tester until the weight platform floats about 1/4 inch above its rest position. Rotate the weight platform by hand. While maintaining a constant pressure with the pump, loosen the fitting at the test instrument and purge all air from the system. When the air bubbles are no longer noticed in the escaping fluid, tighten the fitting.

Place on the top of the weight platform the weights necessary to produce an approximate full-scale indication on the test instrument. Then proceed as follows:

1. Apply pump pressure until the weight platform is floating; rotate the weight platform by hand. This platform must be turning when readings are being taken from the test instrument.
2. Open the valve that relieves pressure on the test instrument, releasing the pressure slowly.
3. Repeat steps 1 and 2 above twice to exercise the bourdon tube.
4. Release all pressure from the test instrument and tester, then remove the weights from the platform. Be sure that all pressure is released from the tester before removing the weights. If the weights are removed before pressure is released, the piston could come out of the tester, under pressure, damaging the tester and injuring personnel.

Select ten equally spaced calibration values covering the range of the test instrument and record them in the FUNCTION TESTED column on the calibration checklist form. Next, compute the true pressure from the weights that will be used for each test instrument calibration value, using the formula in appendix I of this rate training manual. These true pressure values (in psig) are recorded as the nominal values for each test instrument calibration value in the linearity and hysteresis tests.

LINEARITY TEST (UPSCALE).—Conduct the linearity test as follows:

1. Place on the weight platform the weights that will produce the actual or approximate pressure of the first test instrument calibration value.
2. With the pump, increase pressure until the weight platform floats about 1/4 inch above its rest position.
3. Rotate the weight platform to minimize friction and provide even lubrication to the piston.
4. Tap the test instrument and record the indication on calibration checklist. Read the test instrument while the platform is rotating and floating freely.
5. Stop the platform from rotating and place the appropriate weight on the platform that will produce the actual or approximate pressure of the next test instrument calibration value.
6. Repeat steps 2 through 5, continuing until each test instrument value indicated on the calibration checklist form, including full scale, is used.

HYSTERESIS TEST (DOWN SCALE). — Conduct the hysteresis test as follows:

1. Remove from the platform all weights except the one or ones that will produce the actual or approximate pressure of the first test instrument calibration value below full scale.
2. Slowly open the relief valve until the weight platform is floating about 1/4 inch above its rest position. DO NOT GO BEYOND THE BALANCE POINT AND THEN RETURN AS THIS WILL INTRODUCE AN ERROR IN THE HYSTERESIS RUN. The return is a linearity function and will not indicate hysteresis error.
3. Rotate the weight platform, then tap the test instrument and record the indication. Read the test instrument while the platform is still turning.
4. Repeat steps 1 through 3 for each of the other test instrument values indicated on the calibration checklist form.

REPEATABILITY TEST. — To set up the repeatability test, the operator selects the previously calibrated nominal values which are approximately 1/4, 1/2, and 3/4 of full scale, recording them in the FUNCTION TESTED column on the calibration checklist form. Then he records the true pressure values (in psig), obtained in computing the true pressure of the weights, as the nominal value for each test instrument calibration value. Next, he repeats steps 1 through 4 of the linearity test for these three values. Finally, he secures the tester after releasing all pressure and removing the weights from the platform. The tester is secured with its relief valve open and the tester connection covered.

TEST INSTRUMENT EVALUATION. — Complete the calibration checklist form and verify that the test instrument is in acceptable condition. If not, take the required corrective action in accordance with the manufacturer's manual or local MIRCS practices. Then repeat the applicable portion of this procedure.

TEMPERATURE MEASUREMENT INSTRUMENTS

Shipboard instruments for measuring temperatures include a variety of thermometers, pyrometers, and thermocouples. These instruments must be calibrated and adjusted regularly in accordance with approved procedures.

SPEEDOMAX RESISTANCE THERMOMETERS

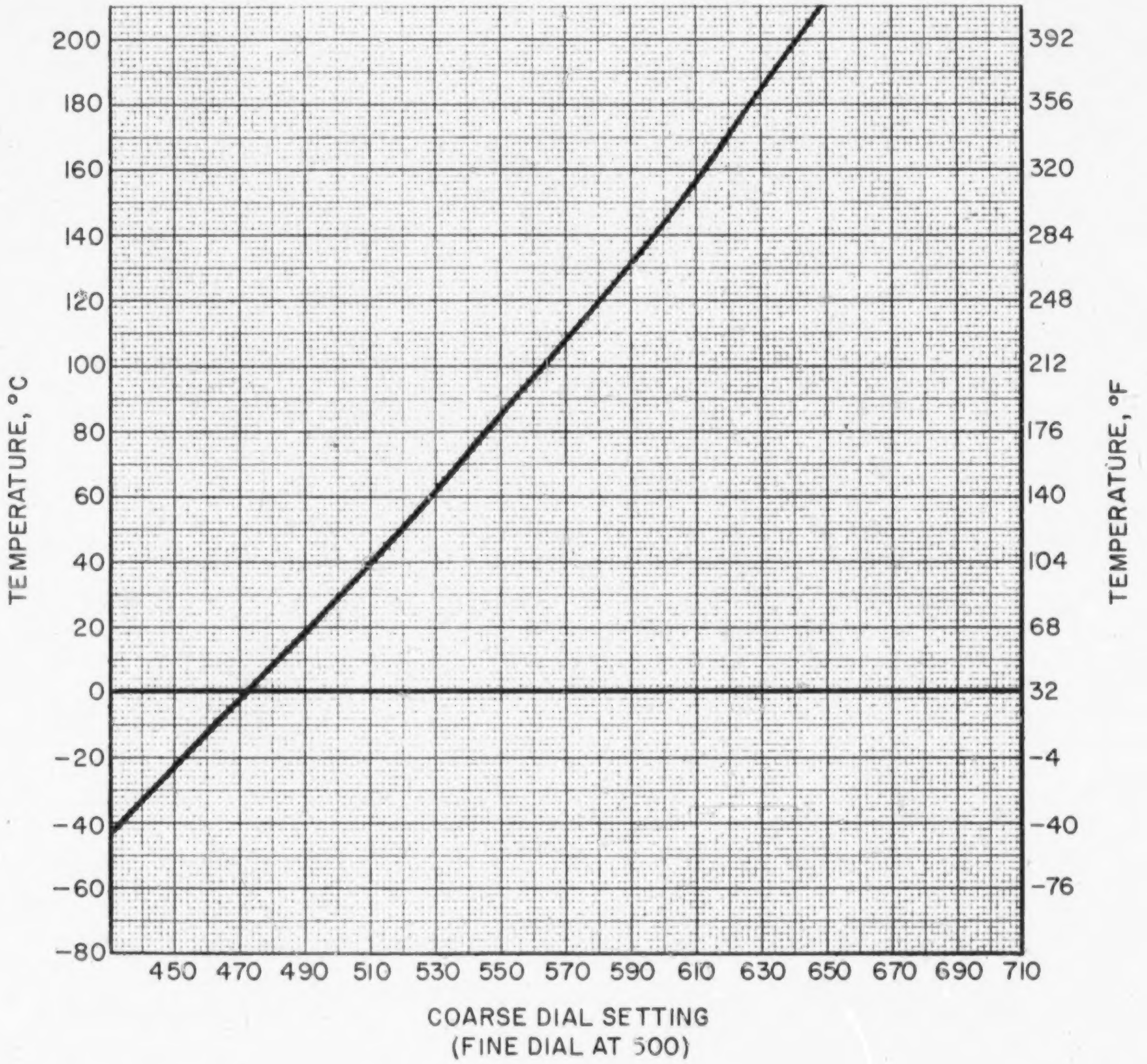
The techniques for adjusting Speedomax thermometers were described in the preceding chapter. Each Speedomax must be calibrated periodically with the length of its calibration cycle being determined by the amount of use the temperature baths get but never to exceed 6 months. Calibration is also required when a range card and scale change is made. The Speedomax is calibrated in place by MIRCS personnel, using ASTM reference standard thermometers.

Each temperature bath must have graphs, such as figures 5-11 and 5-12, to determine the proper setting of the coarse and fine adjusting dials of the controller for a given temperature. It is a good shop practice to recheck or make up a new graph when calibrating the Speedomax.

ASTM thermometers (standards) in their current calibration cycle for the full range of the bath are required. A piece of graph paper is required to show temperatures corresponding to coarse dial settings of the controller. All calibration data for the Speedomax must be recorded on a calibration checklist.

Calibration Procedure

Be sure the stem and bulb of the standard are clean, free of grease and oil, and dry

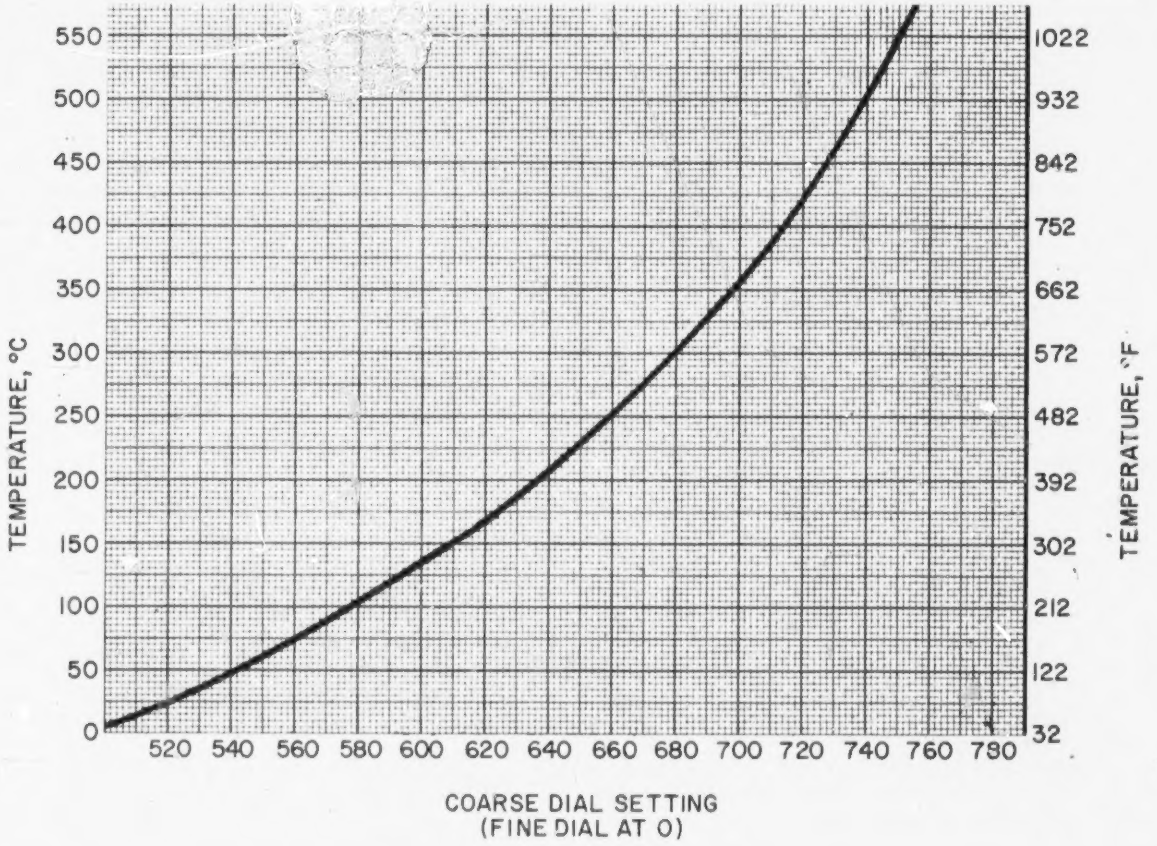


91.582

Figure 5-11.—Approximate calibration of controller.

before placing the thermometer in the test medium. In the high temperature bath, place the thermometer against the salt before heating. After the salt melted, then put the thermometer in place. Allow fifteen minutes for the standard to stabilize to the ambient temperature of the bath.

Make the first calibration run on the bath to check its operation. Turn on the controller. Set the coarse dial at approximately midrange. On the low temperature bath the fine dial is set at 500. On the medium and high baths, the fine dial is set at 0. When the bath reaches set temperature, record the indication of the ASTM thermometer, Speedomax, and the coarse dial. Turn the coarse dial to full range. When the scale indication of the Speedomax has been



91.583

Figure 5-12. — Approximate calibration of controller.

reached, allow the bath to stabilize, (when hunting is not indicated by the on-off period of the pilot light). Record the temperature of the Speedomax, the ASTM thermometer, and the coarse dial setting. Turn the bath off and allow its temperature to return to the ambient or near ambient temperature.

Graph the points that correspond to the coarse dial setting and temperature noted in the first run on the graph paper. This graph will give you the approximate settings of the coarse dial for the calibration points.

Select ten equally spaced calibration checkpoints on the Speedomax and record them on the calibration checklist. Carry out the second run as follows:

1. Set the coarse control to approximately the first calibration checkpoint as noted on the graph.
2. Allow the bath to stabilize.
3. Record the standard and Speedomax indications.
4. Record the setting of the coarse dial.
5. Repeat the above steps for each remaining calibration checkpoint.

Complete the calibration checklist. Check the coarse dial setting and temperatures noted against the graph, and make necessary corrections to the graph.

Temperature Bath Controller Adjustments

To obtain maximum control of the temperature in the calibration bath, it is necessary to accurately adjust the temperature controller gain and reset times. These controls are located on top of the chasis and are labeled GAIN and RESET. Remove the four corner mounting screws on the front panel and withdraw the temperature controller from the cabinet to reach to control knobs as shown in figure 4-19.

With the controller correctly connected to the bath, adjustments are made as follows:

1. Set GAIN to position 9, RESET to on-off and the coarse and fine temperature control dials to the desired temperature.
2. After the heater has cycled a few times, determine the number of seconds it takes to complete a cycle (OFF to ON to OFF). One way of doing this is to watch the pilot light on the front panel and measure the time, starting when the light just goes out at the end of the long ON period to the time it just goes out at the end of the next long ON period. Make a note of the time period.
3. Set RESET to P (proportional) and adjust GAIN to the maximum value that will not cause hunting. Since the controller proportions the heat output by time cycle modulations, the pilot light indicates proper operation by going on and off regularly about once per second. Hunting exists if the pilot light periodically increases and decreases its duty cycle or ON time. This action is not to be confused with on-off type operation.
4. Complete the adjustment by setting RESET to the number of seconds noted in step 2 above or to the next position of higher value.

LIQUIDOMETERS

The liquidometer, a float-actuated, remote-reading gage, is an example of the hydraulic-type tank level indicator. Its most common usage is on the safety, trim, and negative ballast tanks of submarines.

OPERATING PRINCIPLE

The liquidometer operates on the principle of a balanced hydraulic system, as illustrated in figure 5-13, with operating power derived from a mechanical float and arm movement and the liquid (triple-distilled kerosene) in the transmission system. Two metal bellows in each tank unit are connected with the two bellows in the dial unit through transmission lines.

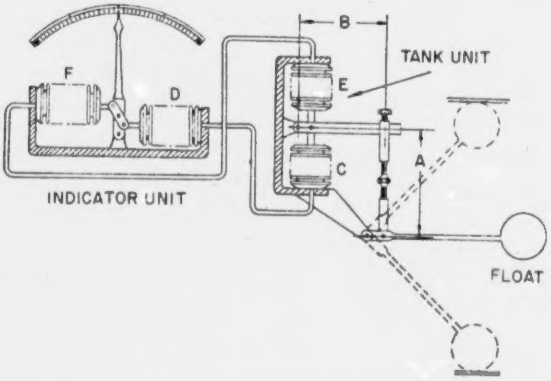


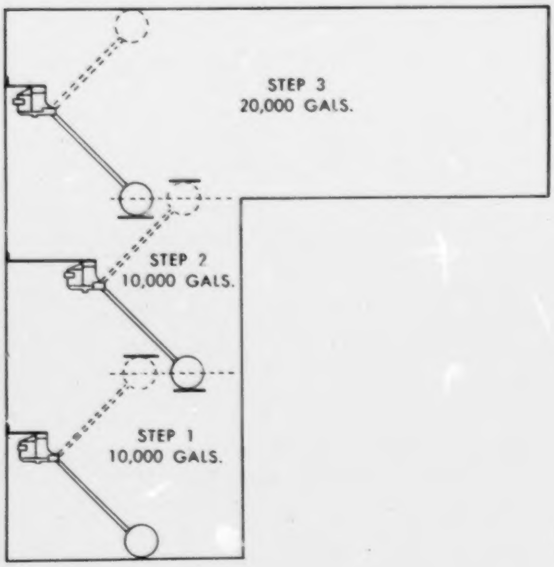
Figure 5-13.—Drawing showing principle of liquidometer gage. 91.585

The basic liquidometer system consists of an indicator assembly, a tank unit (with its float and float arm) and the transmission lines (capillary tubes) connecting the indicator with the tank unit and terminating in a line coupling box near the tank unit.

When the float moves down, the mechanical linkage between the float arm and the tank bellows compresses bellows C, figure 5-13, and displaces a portion of the liquid in the transmission system; this liquid travels by way of the transmission tubing into bellows D of the indicator unit, causing the bellows to expand. At the same time, bellows E (tank unit) expands because of its connection with the downward-moving float arm, and takes in more liquid by way of the transmission tubing from bellows F in the dial unit. The movement of liquid from F to E causes F to contract and move the pointer. When the float arm moves upward, the entire operation is reversed.

Multiple-Step Gages

Liquidometers in large tanks usually have 2, 3, 4, or 5 float units, called multiple-step gages. Each float unit, through its pointer, acts over a separate section of the dial in proportion to the volume it measures (fig. 5-14). If the dial is to be graduated evenly, the upper float unit


STEP 3
20,000 GALS.
STEP 2
10,000 GALS.
STEP 1
10,000 GALS.

91.586
Figure 5-14.—Typical irregularly shaped tank.

must register over more of the dial than either of the other two units. See figure 5-15.

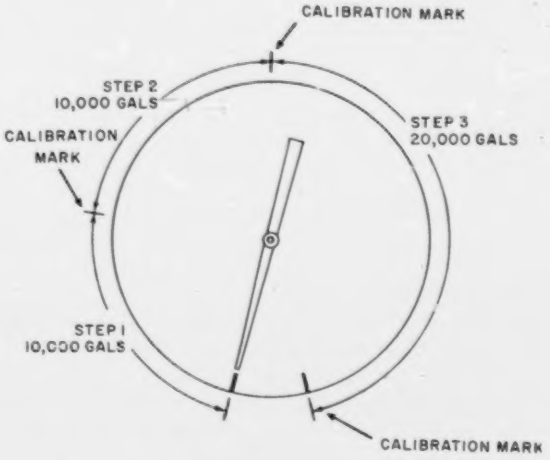
Stroke-Setting Dial

To set stroke on a multiple-step gage, it is first necessary to make up a stroke-setting dial by: (1) setting the stroke for each step in its neutral position and (2) setting the stroke for each step, so that the pointer travels correctly from the EMPTY to the FULL mark on the dial.

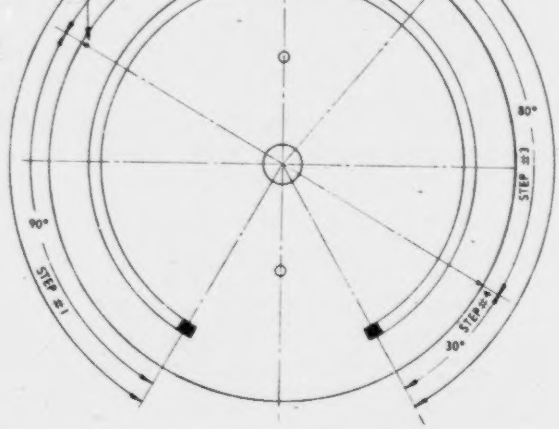
On all but the oldest submarines and surface vessels the permanent dial is marked with white dots near its outer edge. These dots indicate the limit of pointer travel for each step, and are used for final stroke setting. The preliminary stroke-setting dial, which must be prepared first, is made up as follows:

Remove the permanent dial from the indicator unit and lay it on a sheet of clean paper. Draw lines from the center of the dial through the white dots, extending them a few inches onto the paper below the dial (figure 5-16). Lay off the number of degrees for each step with a protractor; the total number is 300 degrees.

Now, using the new blank paper dial, mark the travel of each step in degrees with a red pencil, showing one-half of the motion to the left and the


CALIBRATION MARK
STEP 2
10,000 GALS
STEP 3
20,000 GALS
CALIBRATION
MARK
STEP I
10,000 GALS
CALIBRATION MARK

91.587
Figure 5-15.—Volumetric division of total pointer travel.

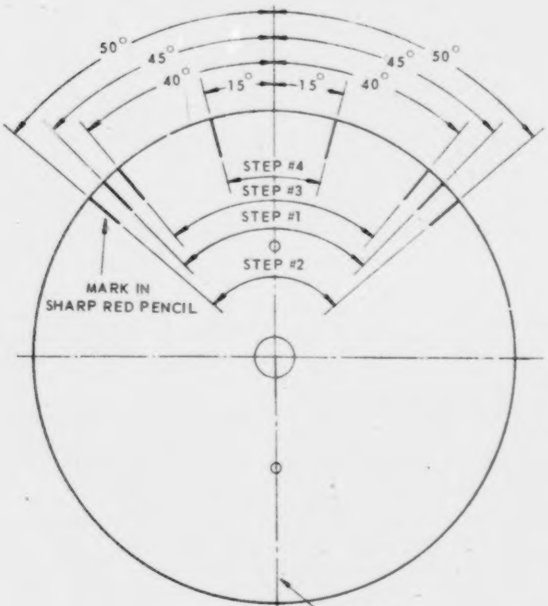

WHITE DOT MARKS
300°
100°
STEP # 2
80°
STEP #3
90°
STEP #1
STEP #4
30°

91.588
Figure 5-16.—For setting stroke on multiple-step gages, a preliminary new dial is prepared, using the white dot marks on the permanent dial.

other half to the right of the centerline. Identify the steps, as shown in figure 5-17. This paper dial can now be attached to the indicator unit and used for the purpose of calibrating the permanent dial so that the pointer will travel correctly from EMPTY to FULL for each step. If a new finished metal dial is desired, send the calibrated paper dial to the manufacturer who will furnish a new permanent dial made in accordance with this calibration.

CALIBRATING A LIQUIDOMETER

The calibration of a liquidometer requires three men when only one dial indicator is involved and four men when two dial indicators are in use. Each man stationed at an indicator is in phone contact with one man in the tank and gives him adjustment directions in terms of flats. (A flat equals one-sixth of a turn of a hex nut.) Another man must serve as a line tender or safety man at the top or opening of the tank.



91.589

Figure 5-17.—The stroke-setting dial is completed by transferring the float motion in degrees to the paper dial.

Preparing for Tank Entry

The tank should be opened, vented, and flushed with air for a 24-hour period. Afterward, the ship's safety officer must check the tank for presence of explosive gases, and make sure the air in the tank is breathable. The senior petty officer in charge of the calibration should accompany the safety officer to verify his readings. A man must not enter the tank until an air supply (blower or ship board air supply) is rigged for use in the tank.

Station a man at the opening of the tank as a safety man and lifeline tender for the man in the tank. Be sure the inside man is tied to one end of the lifeline so both hands are free for making adjustments. Also the other end of the line must be attached to a solid object near the work area to prevent him from falling to the bottom of the tank in case he slips. The safety man must occupy a position outside the tank from which he can always see the man inside.

Rig a portable sound-powered phone with headsets, one for the man in the tank and one each for the men at the dial indicators.

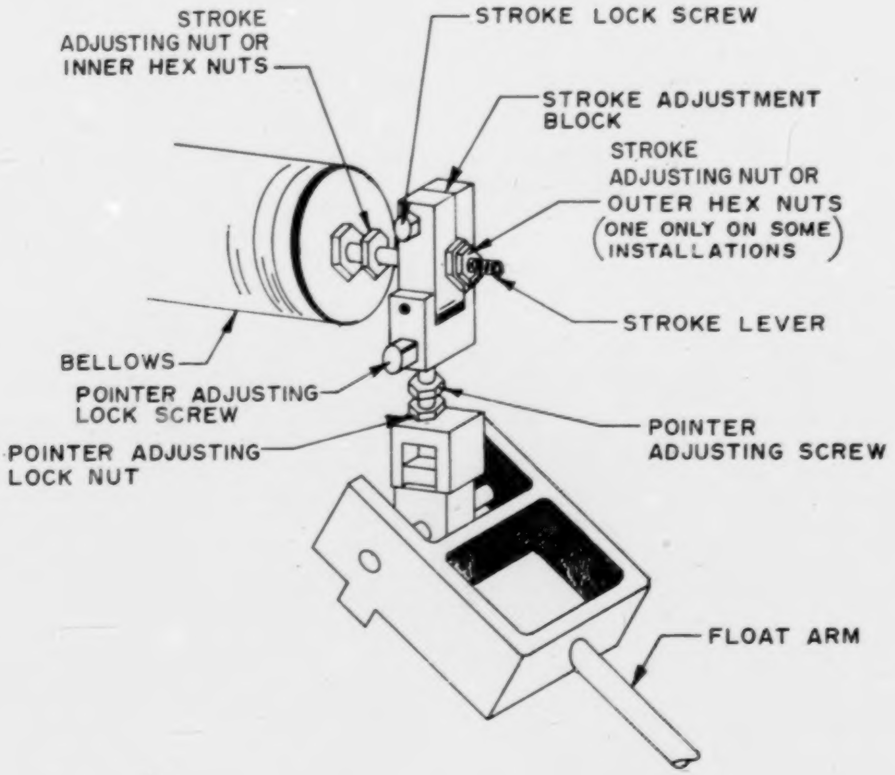
Inspection

Before any adjustments are made, inspect the system to make sure the lines are free of air bubbles and in good working order. The tank unit housing should be free of air or contents of the tank. If any are found, the housing must be flushed with kerosene and dried, then refilled with oil. Look for leaks, indicated by kerosene seeping out of joints in lines, tank units, or dial indicator. Only nonsparking tools and safety-approved lighting may be used in the tank. Do not stand on parts of tank units; lines and parts may be pulled loose, bent, broken, or kinked.

Calibration

In a multistep unit, calibrate the lowest float unit first. Tie it against the upper stop and proceed to the next float unit.

Raise the float to its upper stop; do this slowly to avoid straining or rupturing the bellows and transmission tubing. Check whether the total distance traveled by the pointer is approximately equal to the distance between the full and empty calibration marks on the dial. Move the stroke adjusting block until the stroke is approximately correct and lock the stroke adjustment with the locknut.


STROKE ADJUSTING NUT OR INNER HEX NUTS
STROKE LOCK SCREW
STROKE ADJUSTMENT BLOCK
STROKE ADJUSTING NUT OR OUTER HEX NUTS (ONE ONLY ON SOME INSTALLATIONS)
STROKE LEVER
BELLOWS
POINTER ADJUSTING LOCK SCREW
POINTER ADJUSTING LOCK NUT
POINTER ADJUSTING SCREW
FLOAT ARM

91.590

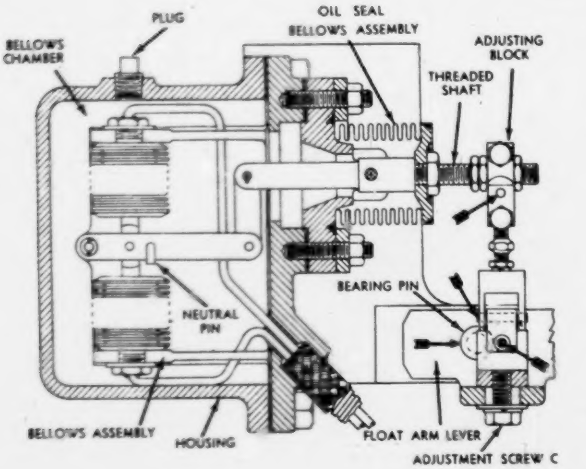
Figure 5-18.—Typical stroke and pointer adjustments on float actuated hydraulic liquid level indicators.

ADJUSTING THE STROKE AND POINTER.— Increase the stroke by loosening the stroke adjusting block lockscrew and turning the stroke adjusting nut (fig. 5-18) so the adjusting block moves in toward the bellows. Moving this block away from the bellows decreases the stroke. (Stroke is the range or distance the pointer travels when a float is raised or lowered.) The locknut at the bottom of the pointer adjusting screw must be loosened before the pointer adjusting screw is turned. Turn the pointer adjusting screw clockwise to move the pointer up scale (or clockwise) and counterclockwise to move the pointer down scale.

PROCEDURE.— Place the float against the bottom stop and check to see if the pointer indicates empty or is on the lower calibration mark. In tanks that cannot be pumped completely dry, hold the lower float against the stop under water. Adjust with the pointer adjusting screw until the pointer is on the lower calibration mark and lock the pointer adjustment.

Raise the float to the upper stop, then check whether or not the pointer comes on the upper calibration mark on the dial. If the pointer is either over or under the mark, split the distance and make another stroke adjustment to bring the pointer to the halfway point between the upper calibration point and where the pointer was when raised. Lower the float and check the pointer adjustment by repeating all the above steps until the pointer reads exactly on both upper and lower calibration marks. If enough adjustment cannot be obtained by means of the adjustment block (fig. 5-19), turn screw C.

Tie the first float to the upper stop position and proceed to the second float.



91.591

Figure 5-19.—Interior details of liquidometer tank-unit adjustment assembly. Heavy arrows show points where binding may occur.

Raise the second float to the upper stop and see if total distance traveled by the pointer is approximately equal to the distance between the upper and lower calibration marks on the dial. Adjust this float unit and subsequent units as described above.

After completing the adjustments for all steps, untie all the floats and lower them slowly to their bottom stops. Lower the top float first, then the rest in the order that they were raised. Make certain that all adjustments are locked. Before leaving the tank, be sure all tools and loose materials are removed from it.

LIQUIDOMETER MAINTENANCE

The preliminary inspection or calibration of a liquidometer may indicate that it needs refilling. A slow, sluggish, or nonmoving pointer indicates a break in the lines or that the lines do not have a solid fill due to air, water, or some other foreign matter in them. A solid fill in the lines is essential for good calibration. Check also for kinked lines or collapsed transmission tubing.

Foreign matter in lines is removed by flushing. To flush the lines, break the connections at the tank coupling box and indicator connection box and force clean kerosene through the lines. Use nitrogen to purge the lines and remove moisture. Nitrogen also helps to locate hard-to-find leaks in lines. With soapy water around the lines and slightly pressurized nitrogen inside, bubbles will form at a leak.

Filling a Liquidometer System

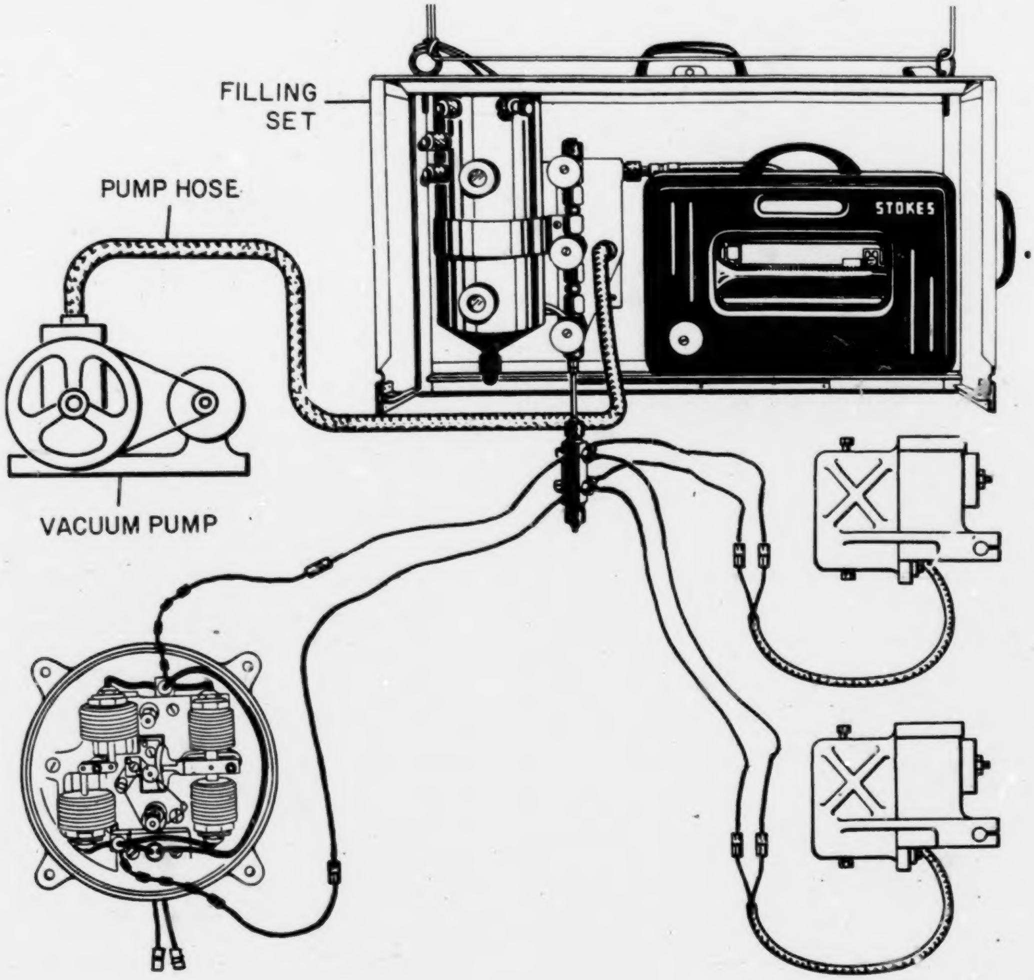
A liquidometer system is filled by means of a filling set arranged as shown in figure 5-20. The set consists of a reservoir for kerosene, a McLeod gage for reading degrees of vacuum in microns, a vacuum pump for evacuating air from the system and a valve manifold for opening and closing lines to the McLeod gage, the vacuum pump, and the reservoir. Kerosene is admitted after air is removed.

To prepare the filling set for use, hang it at a convenient location; remove the front and bottom panels, then the support rod. Place the vacuum pump within six feet of the filling set.

The O-rings in the filling set need changing at least once a month. Replace them oftener if they develop flat spots. When replacing the O-rings, coat them with a high vacuum grease.

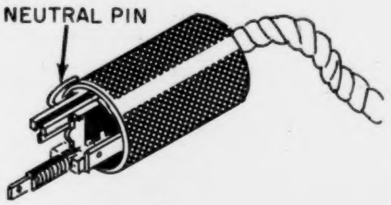
FILLING PROCEDURE.—Connect the reservoir valve to the reservoir and the vacuum pump, using neoprene hose. Fill the reservoir with kerosene. Evacuate the reservoir to dissolve air from the kerosene. To evacuate, close the valves and start the pump; next, open the pump and reservoir valves and run the pump two hours. Then close the reservoir valve. Remove the neoprene hose and connect the vacuum pump to the pump valve with metal hose. At this time change oil in the vacuum pump.

To evacuate the junction box and tank units, cap the junction box lines at the tank unit ends. Couple the appropriate filling leads to the filling manifold, mainline end of the junction box and the tank units. Close all valves and start the pump. Open the pump and manifold valves, then operate the pump for two minutes. Open the gage control valve and take a vacuum reading. Wait 5 minutes and take a second reading. If the difference is greater than 100 microns, repeat the preliminary steps. If the difference is still greater than 100 microns, check for leaks or vapor in the lines. When no leaks are noticeable, start the pump; next, open the valve and pump for at least two hours. Then close the pump valve and secure pump. This vacuum reading should be 25 microns or less. Wait 5 minutes and take a second reading. The difference between the first and second readings should be 25

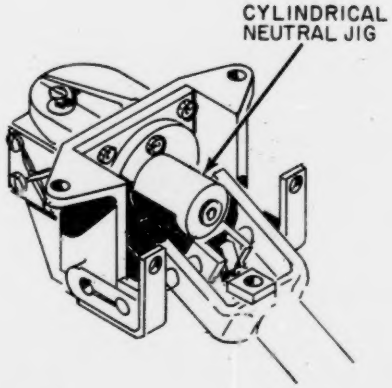

FILLING SET
PUMP HOSE
VACUUM PUMP
STOKES

91.592

Figure 5-20.—Filling arrangement.



51.593.1
Figure 5-21A.—Installation of neutral pin on external mount tank units.



51.593.2
Figure 5-21B.—Installation of neutral jig on internal mount tank units.

microns or less. If necessary, repeat this procedure until satisfactory readings are obtained, then close all valves. ENSURE THAT THE VACUUM GAGE VALVE IS COMPLETELY CLOSED.

To inject kerosene into the units, open the kerosene valve, remove the plug from the vent and allow two hours for the vacuum to draw kerosene into the units. Then slowly stroke the lever of the Step-1 tank unit up and down a few times to draw in kerosene. Repeat this procedure with the remaining tank units.

To connect the tank units to the juction box, install a neutral pin or jig (fig. 5-21A and B) on the tank unit to bring both bellows to an equal or neutral position. Neutralize all tank units at one time.

With closing off pliers, squeeze the two filling leads to the Step-1 tank unit just below the filling manifold. Make enough consecutive squeezes to flatten a 1/4-inch-long section on the leads, towards the manifold. With cutting pliers, cut off both filling leads below the flattened section. Caution: Do not cut the filling leads between the flattened section and the filling manifold.

To avoid spilling kerosene, raise the ends of the other filling leads on the tank unit. Submerge the junction box leads of the No. 1 tank unit in kerosene and remove the caps from the junction box leads. Connect positive-to-positive line and negative-to-negative line, using new copper washers. NEVER USE A COPPER WASHER MORE THAN ONCE. Keep fittings immersed in kerosene when making and breaking couplings to prevent loss of kerosene. Connect other junction box leads and tank unit leads in the same manner. The indicator and main transmission lines are also connected in the same manner with the indicator filling leads.

CHAPTER 6

REPAIRING WATCHES AND CLOCKS

This chapter is divided into three main parts: (1) analyzing casualties in watches and clocks, (2) replacing watch or clock parts, and (3) repairing watch or clock parts. The first part defines casualty analysis and contains a chart that lists possible causes and remedies for common faults in watches. The second part deals with procedures for replacing defective or broken balance staffs, cannon pinions, and mainsprings. The third part is devoted to the functioning and repair of the escapement and to a procedure known as hairspring manipulating.

Although this chapter gives many details and procedures pertaining to watch repair, bear in mind that watch repair is highly technical and delicate work which can be mastered only through experience, which you will receive under competent supervision in Navy instrument shops.

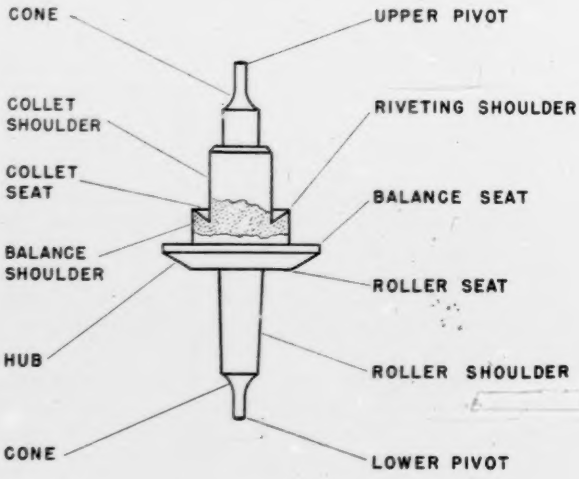
CASUALTY ANALYSIS

When a watch is brought to the instrument shop for repair, your job as an Instrumentman on duty in the shop is to locate the trouble and eliminate it. In doing this, you make what is known as a CASUALTY ANALYSIS—you inspect and disassemble the watch as necessary until you locate the difficulty. Enter your findings on the casualty analysis report.

Table 6-1 is a TROUBLESHOOTING CHART which will help you locate trouble in a watch mechanism. It covers most of the difficulties you will encounter in watch repair, and you should study it and use it as a reference.

REPLACEMENT OF WATCH PARTS

This section gives the procedures for replacing defective or broken watch parts—balance staffs, cannon pinions, and mainsprings. It also describes the maintrain and shows how you can determine the number of teeth in a lost wheel and the number of leaves in a missing pinion.



61.83.1X
Figure 6-1.—Nomenclature of a typical balance staff.

REPLACING A BALANCE STAFF

As you learned in previous study, the balance staff is the shaft on which the balance wheel is mounted. The rotating axis around which the balance wheel oscillates is formed by a line running through the pivots at each end of the staffs. The pivots fit in jewels capped by endstones. Study carefully figure 6-1, which shows a typical balance staff and lists the nomenclature. Then take a look at two defective balance staffs illustrated in figure

Table 6-1. — Troubleshooting Chart

Fault	Cause(s)	Remedy
Crown unscrews.	Stem rusty.	Remove the rust.
	Threaded portion of stem is burred.	Remove burs with a fine file or with an oilstone.
Stem pulls out.	Loose stem screw.	Tighten the detent screw.
	Damaged stem.	Replace the detent.
Stem will not stay in winding position.	Shoulder on detent is worn.	Replace the stem.
	Square on detent is too long.	
	Clutch lever spring is broken.	Replace the clutch lever spring.
Watch stops; has trouble in winding mechanism.	A broken clutch lever spring allows the clutch pinion to engage the setting wheel.	Replace the clutch lever spring.
	Worn shoulder allows the watch stem to shift into the setting position.	Replace the watch stem.
The watch cannot be fully wound.	The mainspring is broken.	Replace the mainspring.
	The barrel cover is disengaged from the barrel.	Reassemble the barrel assembly.
	The click spring is broken.	Replace the broken click spring.
	Dial is too loose, causing the second hand to become fouled up.	Tighten the dial screws.
Watch stops; has faulty dial.	The dial is not centered properly, causing the hour wheel and second wheel and second hand pipe to bind on it.	Position the dial by changing the location of dial feet. Avoid breakage.
Watch stops; hands not properly positioned.	Hands touch the dial or the crystal.	Adjust hands as necessary to have them move parallel with the dial.
	The hands catch.	Adjust, as above.
	The hour hand pipe binds on the hole in the dial.	Center the dial.
	The minute hand hub binds on the hour wheel hub.	Set the hour hand and the minute hand squarely on the hour wheel and the cannon pinion, respectively.
Hands fail to indicate correct time.	The hands are loose on the hour wheel or the cannon pinion.	Tighten the hands in the 12 o'clock position with the watch set for this position.
	Hands are improperly set.	
	Hour and minute wheels are enmeshed.	
	Watch runs; hands fail to move.	Place the dial washers on the hour wheel between the hour wheel and the dial. Tighten the cannon pinion.

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Table 6-1.—Troubleshooting Chart—Continued

Fault	Cause(s)	Remedy
	THE ESCAPEMENT	
The roller jewel is out of action with the fork slot.	Pallet jewels are not set properly.	Reset the pallet jewels.
	The guard pin is bent.	Straighten and adjust pin.
	Guard pin is broken.	Replace the guard pin.
	Guard pin is too short.	Replace the guard pin.
	The fork is bent.	Straighten the fork.
	There is too much sideshake or endshake in the pallet or balance.	Adjust bridges or replace the staffs, bushings, or jewels.
	The banking pins are not adjusted properly.	Adjust the banking pins.
	The roller table is not of the correct size.	Replace the roller table.
Watch stops—the escapement assembly is faulty.	The escapement is dirty or is not oiled properly.	Disassemble the escapement; then clean and oil.
	Pivots are bent or broken.	Straighten or replace pivots.
	The roller jewel is out of action with the fork slot.	Remedy was explained above.
	There were burrs on the escape wheel.	Remove the burrs with an oilstone.
	Some escape wheel teeth are bent or broken.	Replace the escape wheel.
	Some jewels are broken.	Replace the jewels.
	Jewels are improperly set or are loose in their settings.	Reset the jewels.
	The roller jewel is loose.	Reset the roller jewel.
	There is excessive oil on the upper pallet or the staff pivot.	Disassemble, clean, and lubricate.
	BALANCE ASSEMBLY	
Watch stops—balance assembly is faulty.	The balance staff is bent or broken.	Replace the balance staff.
	The balance jewels are loose or broken.	Replace the balance jewels.
	The balance or balance jewels is dirty.	Disassemble, clean, and lubricate.
	The roller jewel is loose or broken.	Tighten or replace the roller jewel.
	The roller table is loose.	Tighten or replace the roller table.
	The hairspring is bent.	Straighten or replace the hairspring.
	The hairspring is broken.	Replace the hairspring.
	There is oil on the hairspring.	Clean the balance unit.
	Hairspring is magnetized.	Demagnetize the watch.
	Balance screws are loose.	Tighten the balance screws.
	The balance is not true.	True the balance wheel.
	The balance wheel is loose on the staff.	Restake the balance wheel on the staff.
	There is a loose balance bridge.	Tighten the balance cock screw.

Table 6-1.—Troubleshooting Chart—Continued

Fault	Cause(s)	Remedy
BALANCE ASSEMBLY—Continued.		
Watch stops—balance assembly is faulty—Continued.	There is excessive endshake or sideshake.	Make necessary adjustments.
	The balance rims strikes the center wheel, hairspring stud, regulator pins, or some other point.	Check the balance jewels for correct position and depth, center the wheel for trueness, check hairspring study for correct position, and the balance cock for burrs on the underside.
	The balance rim strikes the pallet bridge.	Check the lower balance jewels for proper depth, the underside of the pallet bridge for burrs, and the pallet bridge for correct position and tightness.
	The small roller table strikes the lower hole jewel setting shoulder.	Turn the shoulder back or replace the jewel.
	The edge of the safety (small) roller is rusty or gummy.	Buff and polish the edge of the roller with a hand buff.
The watch runs too fast—balance assembly is faulty.	There is oil on the hairspring.	Clean the hairspring.
	The watch is magnetized.	Demagnetize the watch.
	Other coils of hairspring are between the regulator pins with the outside coil.	Release the spring and make corrections.
	Hairspring is twisted or bent.	Straighten or replace hairspring.
	Balance wheel is not properly poised.	Poise the balance wheel.
	The regulator pins bind the hairspring.	Spread the regulator pins.
	Hairspring not correct one.	Replace the hairspring.
	Balance screws are missing.	Replace the balance screws.
	Hairspring strikes the center wheel or some other point.	Adjust the hairspring as required to prevent its touching other parts (adjacent).
	The hairspring and the balance wheel are dirty or gummed with oil.	Clean the balance unit.
	The regulator pins are spread apart too far.	Close the regulator pins.
	The rim of the balance wheel strikes other parts of the watch.	Check the position of the balance as related to the balance cock, pallet bridge, center wheel, regulator pins, or hairspring stud. (Make test with watch in different positions.) Replace balance staff. Replace balance jewel and balance staff, if bent or cut.

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Table 6-1. — Troubleshooting Chart — Continued

Fault	Cause(s)	Remedy
	TRAIN MECHANISM	
Watch stops—the train mechanism is faulty.	**The teeth or pinions of the train wheels are dirty.**	**Disassemble the train and clean it.**
	Movement was improperly oiled, or the oil is gummy.	**Disassemble the train and clean it.**
	Some teeth or wheels are bent.	**Straighten the teeth or wheels; if necessary, replace the wheels.**
	There are burrs on the teeth of the wheels.	**Remove the burrs with an oilstone.**
	The bushings are worn.	**Replace the bushings.**
	There is improper depthing of the wheels and pinions.	**Replace them, or rebush the wheels.**
	There is insufficient endshake or sideshake for the wheels.	**Straighten the pivot or replace the wheels.**
	There is a cracked plate jewel.	**Replace the jewel.**
	The jewels are improperly set.	**Reset the jewels.**
	There is a loose jewel.	**Reset the jewel.**
	The bridge plate is loose.	**Tighten the screw in plate.**

91.173.0

6-2. Note the defects in each one, particularly the damage caused to one pivot by a cracked jewel.

When you replace a defective or broken balance staff, turn the old staff off with a graver. DO NOT ATTEMPT TO KNOCK IT OUT.

There are three types of riveted balance staffs and a friction-fitted type. See figure 6-3, which gives some common forms of riveted balance staffs.

You can remove a standard rivet-type balance staff by turning off the hub under the balance arm, or by turning off the rivet (on top of the balance arm). The turning-off-the-hub method has two advantages and is generally preferred: (1) the balance shoulder of the staff will not be forced through the hole of the balance wheel; and (2) because the staking process hardened the metal in the rivet, the hub is easier to turn than the riveted shoulder. However, if this type of staff cannot be replaced from stock and must be made on a lathe, remove the balance staff by turning off the rivet.

Turning off the Hub

Refer to the illustrations as you study the procedure for turning off the hub of a standard-type balance staff.

Insert the balance staff in a chuck and secure the chuck in a lathe, in the manner shown in figure 6-4. Then hold a sharp, pointed graver at the angle illustrated and shave off the roller seat of the hub. Apply even pressure on the graver.

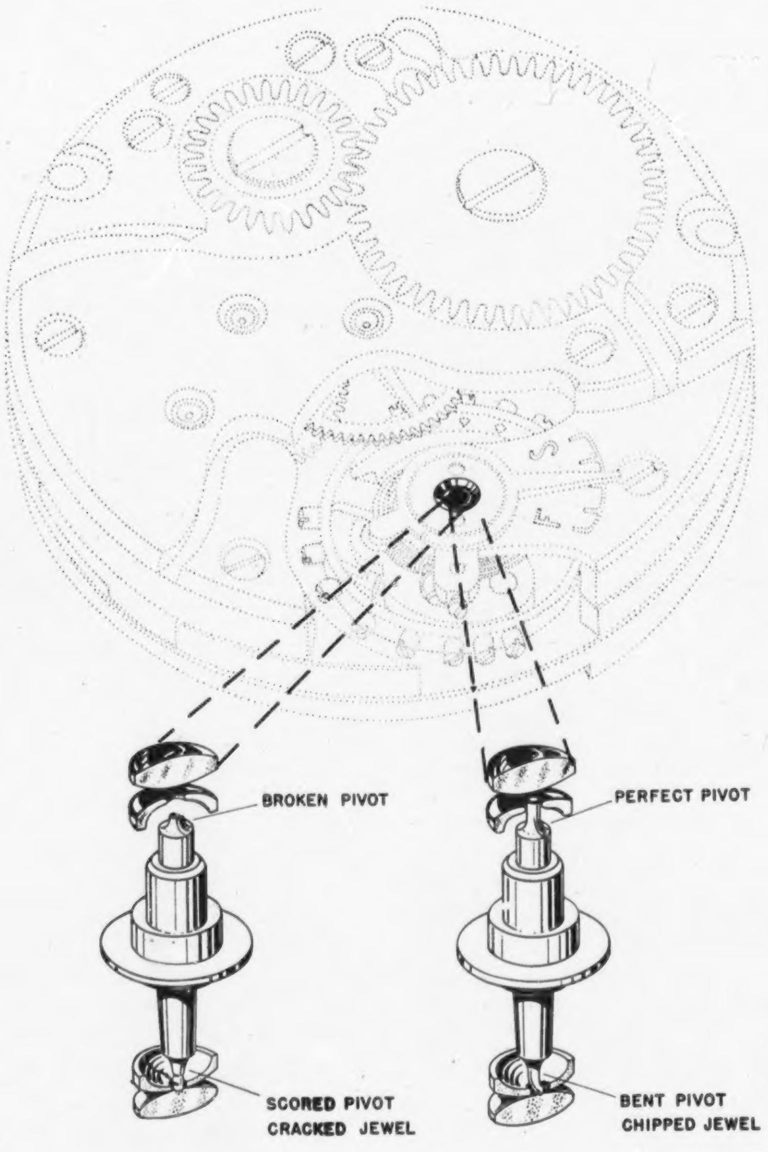
As the shavings begin to fall from the hub, swing the graver slightly to the right. In this position, the point of the graver cuts deeper than the sides into the roller seat, forming a V groove (fig. 6-5).

When you get the metal of the hub turned almost to the balance arm, the point of the graver breaks through (fig. 6-6), leaving a loose ring of metal (outer portion of the turned-off hub). Use care to prevent damage to the balance arm.

You can usually ease the balance wheel off the staff with your fingers; but if it does not come off readily, use a staking tool, as illustrated in figure 6-7.

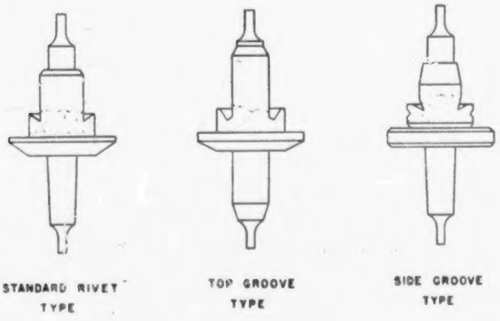
Turning off the Rivet

Exercise considerable care when you turn off the rivet on the arm of a balance wheel. Use a graver in the same manner as for turning off

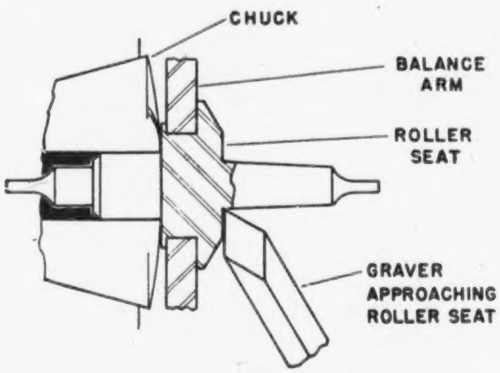

BROKEN PIVOT
PERFECT PIVOT
SCORED PIVOT
CRACKED JEWEL
BENT PIVOT
CHIPPED JEWEL

61.83.2X

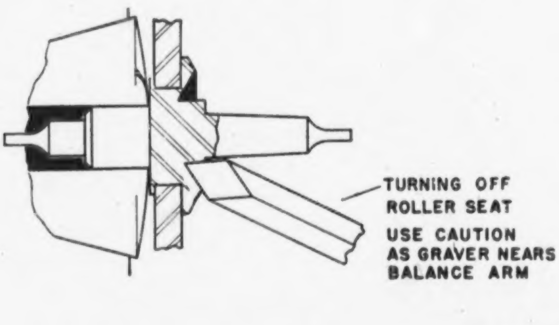
Figure 6-2.—Defects in balance staff.


STANDARD RIVET TYPE
TOP GROOVE TYPE
SIDE GROOVE TYPE

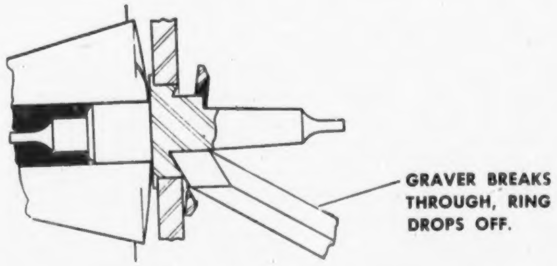
61.83.3X
Figure 6-3.—Common forms of riveted balance staffs.


CHUCK
BALANCE ARM
ROLLER SEAT
GRAVER APPROACHING ROLLER SEAT

61.83.4X
Figure 6-4.—Turning off the hub of standard balance staff.


TURNING OFF ROLLER SEAT
USE CAUTION AS GRAVER NEARS BALANCE ARM

61.83.5X
Figure 6-5.—Turning off the roller seat of a balance staff.


GRAVER BREAKS THROUGH, RING DROPS OFF.

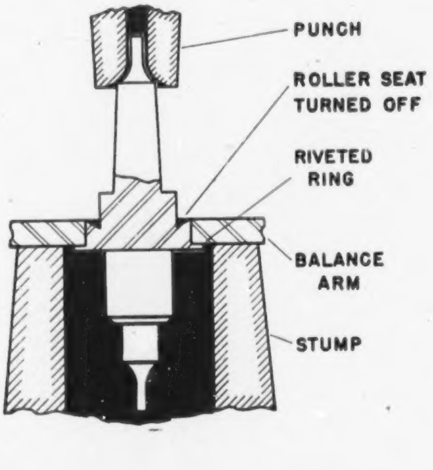
61.83.6X
Figure 6-6.—Graver breaking through the hub of a balance staff.

the hub. Do NOT scratch or damage the balance arm with the graver. The procedure for turning off the rivet is illustrated in figure 6-8.

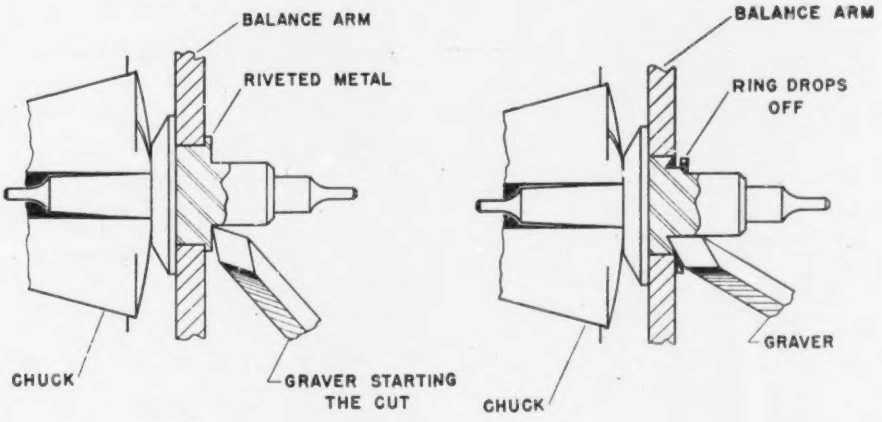
Staking a Balance Wheel

The process for securing a balance wheel to a balance staff is known as STAKING.

The next few paragraphs discuss ONLY the procedure for staking balance wheels on TOP-GROOVE, SIDE-GROOVE, and FRICTION-FITTED balance staffs.


PUNCH
ROLLER SEAT TURNED OFF
RIVETED RING
BALANCE ARM
STUMP

61.83.7X
Figure 6-7.—Removing the balance wheel from the balance staff.


BALANCE ARM
RIVETED METAL
CHUCK
GRAVER STARTING THE CUT
BALANCE ARM
RING DROPS OFF
GRAVER
CHUCK

61.83.8X

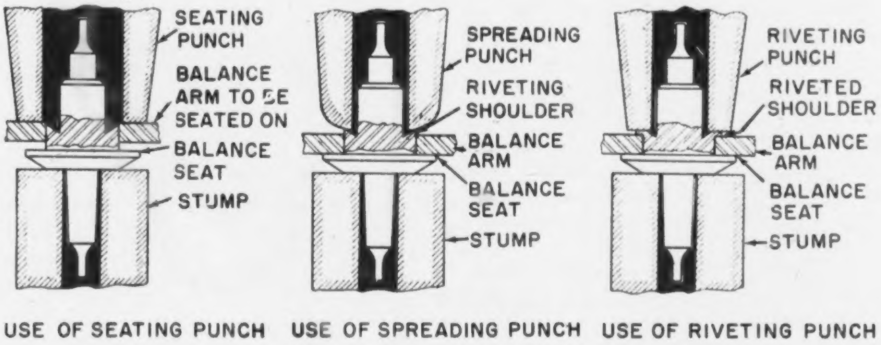
Figure 6-8.—Turning off the rivet of a balance staff.

Figure 6-9 shows the procedure for staking a balance wheel to a top-groove balance staff. Use a flat seating punch with a wide mouth to bring the balance arm firmly into contact with the balance seat. Note that the punch does not touch the seating shoulder. Then use another flat seating punch with a small mouth to hammer the riveting shoulder flat. Use gentle taps with a small hammer. The completed staking job is shown in part C of figure 6-9.

Figure 6-10 shows how to put a balance wheel on a friction-fitted staff. Note in part A that the staking punch has a round nose which fits on top of the hub seat. With a punch of this type, you can bring the hub seat into positive seating position in the hub. Part B of figure 6-10 illustrates the procedure for staking a balance wheel on another type of friction-fitted staff. You need a flat-face staking punch of the size illustrated for pressing the staff into its seated position, with the hub seat on the staff in positive contact with the balance wheel hub.

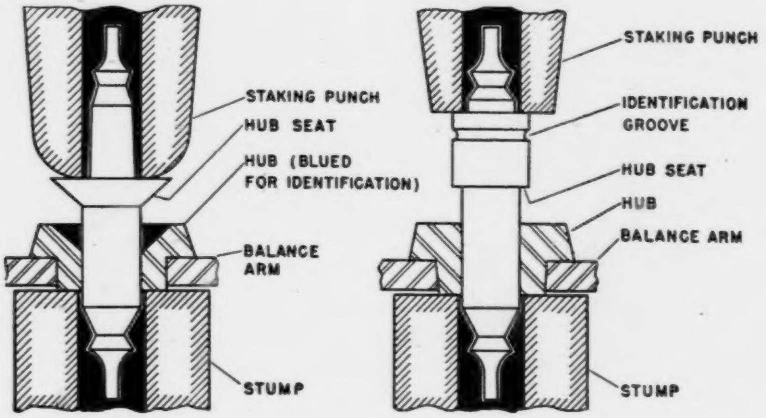
REPLACING A CANNON PINION

The dial train consists of the cannon pinion, minute wheel, and the hour wheel. The cannon


SEATING PUNCH
BALANCE ARM TO BE SEATED ON
BALANCE SEAT
STUMP
SPREADING PUNCH
RIVETING SHOULDER
BALANCE ARM
BALANCE SEAT
STUMP
RIVETING PUNCH
RIVETED SHOULDER
BALANCE ARM
BALANCE SEAT
STUMP
USE OF SEATING PUNCH
USE OF SPREADING PUNCH
USE OF RIVETING PUNCH

61.83.9X

Figure 6-9.—Staking a top-groove balance staff.



61.83.10X

Figure 6-10. —Staking a friction-fitting balance staff.

pinion is a hollow steel pinion mounted on the center wheel arbor. A stud secured in the pillar plate holds the minute wheel meshed with the cannon pinion. Attached to the minute wheel is a small pinion meshed with the hour wheel.

The center arbor revolves once per hour. A hand secured to the cannon pinion on the center arbor travels around the dial once each hour. This hand denotes minutes. The minute wheel is in mesh with the cannon pinion. The hour wheel has a pipe which enables it to sit over the cannon pinion, and it meshes with the minute wheel pinion. The ratio between the cannon pinion and the hour wheel is 12 to 1; therefore, the hand fastened to the hour wheel denotes hours. If the cannon pinion is too tight, it would be difficult to set the watch hands; if it is too loose, the stem turns too freely. When damaged, a cannon pinion must be replaced, as explained next.

Note the position of the cannon pinion in figure 6-11. It is located beneath the hour wheel.

Figure 6-12 shows how to remove the cannon pinion with one type of remover. Lift straight up on the remover to prevent bending or breaking. You can also remove a cannon pinion with a pair of good tweezers or a pin vise.

Before you install a new cannon pinion, thoroughly clean all parts of the dial train, and other parts of the watch. The arbor on which the cannon pinion fits must be free of blemishes and show little wear. Any part which shows wear which may interfere with efficient operation of the mechanism MUST BE REPLACED.

To prevent bending or binding, use much care in fitting a new cannon pinion to the arbor and center wheel. Select proper tweezers for doing the work. A cannon pinion should fit tight, with equal friction all around the center arbor. If it is loose when in position on the arbor, tighten it in the manner illustrated in figure 6-13. Seat it on a tapered, round broach (brass wire) and then move it slightly toward the tapered end

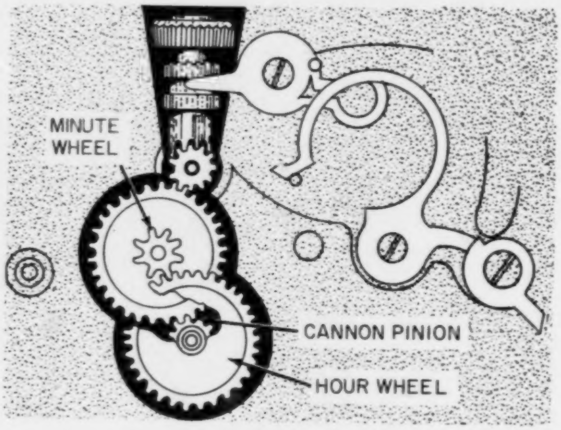


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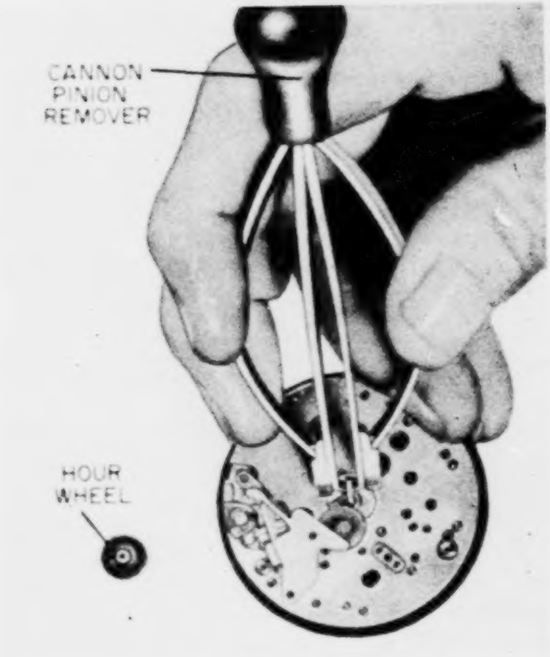
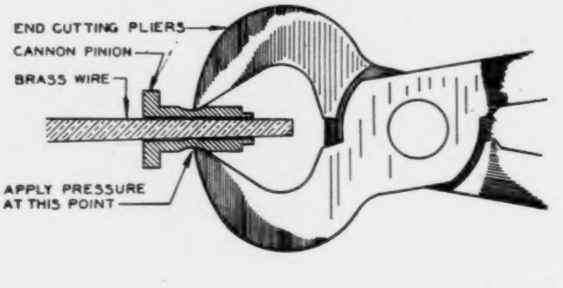
Figure 6-11. — Position of cannon pinion in the dial train.



61.92
Figure 6-12. — Removing a cannon pinion.



91.175
Figure 6-13. — Tightening a cannon pinion.

of the wire. With a pair of cutting pliers (with rounded-off cutting jaws), tighten the cannon pinion at its slot. The tension of the pinion on its arbor should be sufficient to carry the dial train and the hour wheel, but not tight enough to prevent setting of the hands.

Some watch repairmen use steel wire instead of brass wire. Pliers with a setscrew for setting the amount the jaws may be closed are also used. If you use such pliers, close the jaws on the cannon pinion at the spot indicated in figure 6-13 and turn the setscrew in to get the correct measurement between the jaws in this position. Then remove the pliers and unscrew the setscrew just enough to enable you to put the amount of indentation desired on the cannon pinion at the spot indicated. If this does not make the pinion fit tight enough, unscrew the setscrew a little more and repeat the process.

REPLACING A MAINSPRING

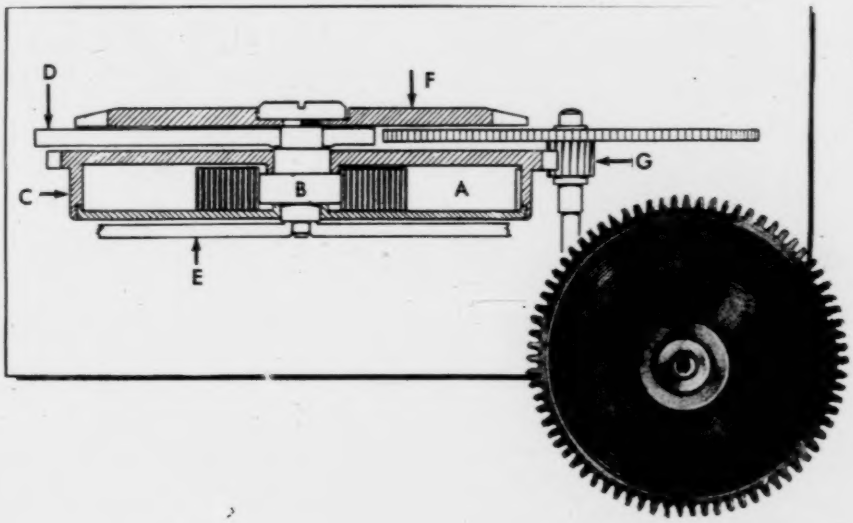
A watch, like an engine or any other mechanical contrivance, must depend on a steady source of motive power. The power assembly in a watch consists of the mainspring, mainspring barrel, arbor, and cap. The mainspring provides essential power to run a watch. It is coiled around the arbor and is contained in the barrel, cylindrical in shape, with a gear on its outer edge, which meshes with the center wheel pinion. This gear is the first wheel of the watch train. The arbor is a cylindrical shaft with a hook in the center for attaching the mainspring. The cap is a flat disk which snaps into a recess in the barrel. The mainspring barrel has a hook on the inside edge to which the mainspring is attached.

Study a watch power assembly (mainspring barrel assembly) in figure 6-14. Note the gear around the top of the barrel in the front view, and then note in the side view how this gear meshes with the center wheel pinion. Study the nomenclature shown in the side view of the assembly. Observe also the position of the ratchet wheel, which turns the barrel arbor when the watch is wound.

A mainspring is made of a long, thin strip of steel, hardened as necessary to give the desired resiliency. Mainsprings vary in size, but each has a hole in the inner end to secure it on the mainspring barrel arbor and a hook on the outer end for attaching it to the mainspring barrel.

Removing Mainspring from Barrel

To remove a mainspring from a barrel, hold the barrel between the thumb and the index finger (with barrel supported on an anvil) and pry off the cap with a screwdriver inserted in the cap slot. Remove the barrel arbor; then grasp the inside



91.176X

Figure 6-14.—Front and side views of a barrel assembly.

coil of the mainspring with tweezers and SLOWLY pull it out of the barrel, allowing it to uncoil gradually.

Thickness of Mainspring

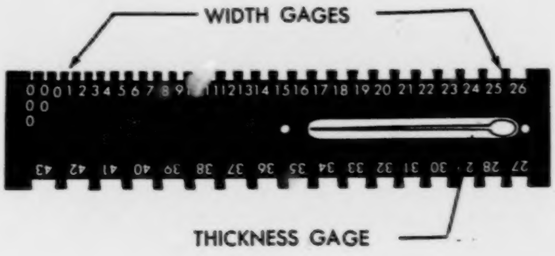
The thickness of a mainspring determines its strength. A spring which is TOO thick causes the motion of a watch to increase beyond safe limits, resulting in the banking of the roller jewel against the pallet fork. Accurate regulation of a watch under such conditions is impossible. On the other hand, if a spring is TOO thin, it does not have sufficient power to run the watch. When you first wind the watch, the balance motion may be satisfactory; but after the weak spring runs a few hours, it does not have enough tension to maintain good running motion of the balance wheel.

If you need a mainspring for a watch of standard make, use a genuine factory-made spring specified by the manufacturer for the specific model. If you do not know the manufacturer of the watch, use a small micrometer or a Dennison mainspring gage to measure BOTH thickness and width of the mainspring required. See figure 6-15.

In determining the proper thickness of a mainspring for a given barrel, take into consideration the following:

1. The INSIDE barrel diameter should be three times as great as a given arbor diameter. The area covered by the spring should be one half the net difference in area between the barrel and the arbor.

2. For a barrel arbor of given size, the mainspring thickness should vary 1/26 to 1/34 of the arbor diameter, depending upon the quality of the movement. Table 6-2 shows that the better the quality of a watch movement the weaker the spring required.



91.177X

Figure 6-15.—Dennison mainspring gage.

Table 6-2.—Guide to Mainspring Thickness

Pocket Watches

7-15 jewels—mainspring thickness, 1/26 arbor diameter
15-17 jewels—mainspring thickness, 1/28 arbor diameter
17-19 jewels—mainspring thickness, 1/30 arbor diameter
19-21 jewels—mainspring thickness, 1/32 arbor diameter
21-23 jewels—mainspring thickness, 1/34 arbor diameter

Wrist Watches

7-15 jewels—mainspring thickness, 1/28 arbor diameter
15-17 jewels—mainspring thickness, 1/30 arbor diameter
17-19 jewels—mainspring thickness, 1/34 arbor diameter

NOTE: Use these figures as a guide ONLY when data from the manufacturer is unavailable. Irregularities in banking, pivots, and depthing, void ALL these rules.

91.422

3. The number of barrel revolutions possible with a given spring is equal to the difference in the number of coils between the WOUND UP and the RUN DOWN positions of the spring.

4. If a spring occupies 1/2 the net difference in area between the barrel and arbor, the last coil when wound up and the first coil when run down both lie on a common circle called the UP AND DOWN CIRCLE (fig. 6-16). When lines AC and BC in this illustration are drawn with 45° angles with the diameter of the mainspring barrel, their point of intersection (C) gives the position of the UP AND DOWN CIRCLE. When the spring is wound in the barrel, the last coil should meet this circle. Line CO is the diameter of the UP AND DOWN CIRCLE.

5. The diameter of the UP AND DOWN CIRCLE is approximately equal to 3/4 the inside barrel diameter when the barrel is ONLY THREE TIMES the arbor diameter.

Length of Mainspring

If a mainspring is TOO LONG, it does not leave enough space in the barrel for unwinding. This means that the watch will not run its maximum number of hours. Take a look at an OVERSIZED mainspring in part A of figure 6-17, and then compare it with the CORRECT SIZE mainspring in figure 6-14.

A mainspring that is too short does not have a sufficient number of coils for unwinding, which means that the watch will not run its maximum

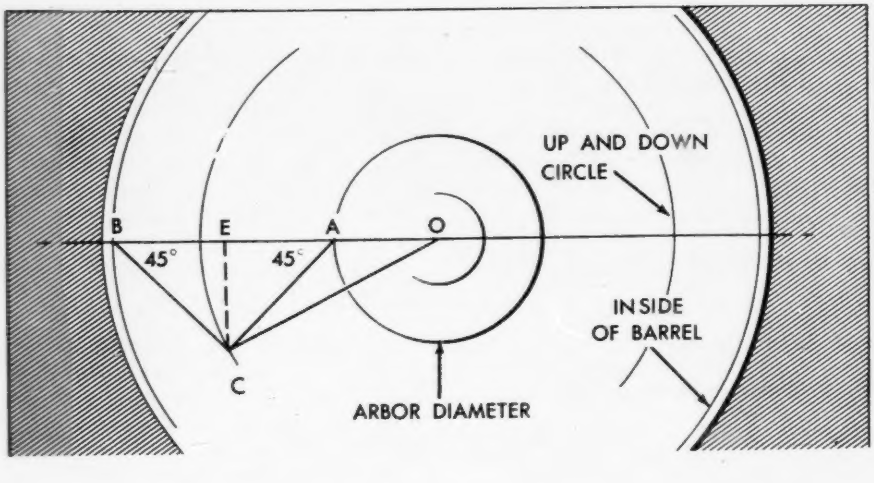


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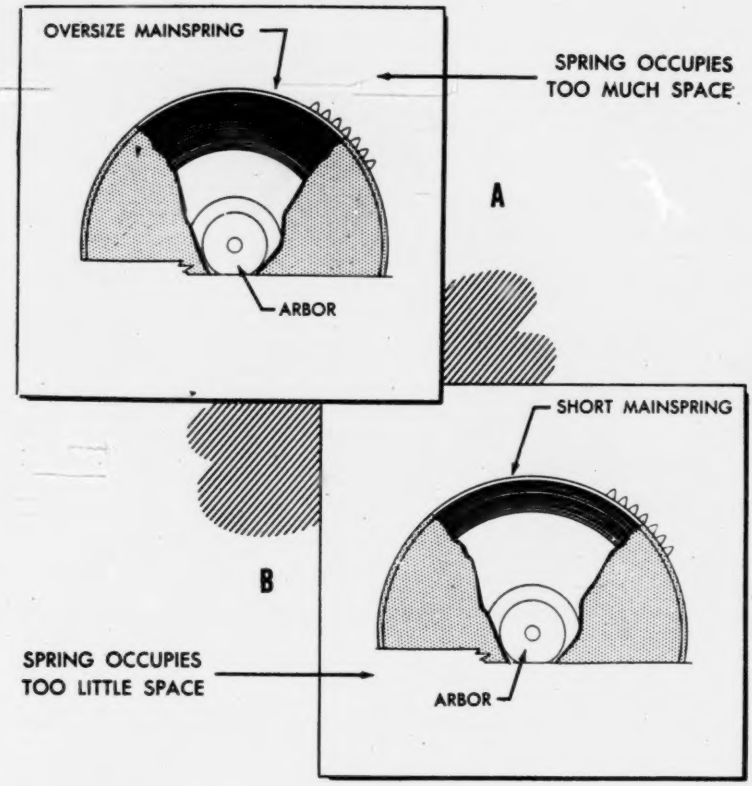
Figure 6-16.—Up and down circle.


OVERSIZE MAINSPRING
SPRING OCCUPIES TOO MUCH SPACE
A
ARBOR
SHORT MAINSPRING
B
SPRING OCCUPIES TOO LITTLE SPACE
ARBOR

91.179X

Figure 16-17.—Over- and under-size mainsprings.

number of hours. Compare the SHORT mainspring in part B of figure 6-17 with the one in figure 6-14.

If you must determine the correct length of a mainspring for a given watch, use W. Dodgion's equation, as follows:

$$\frac{(B+A) \times (B-A)}{64.6 \times T} = \text{length of mainspring in inches}$$

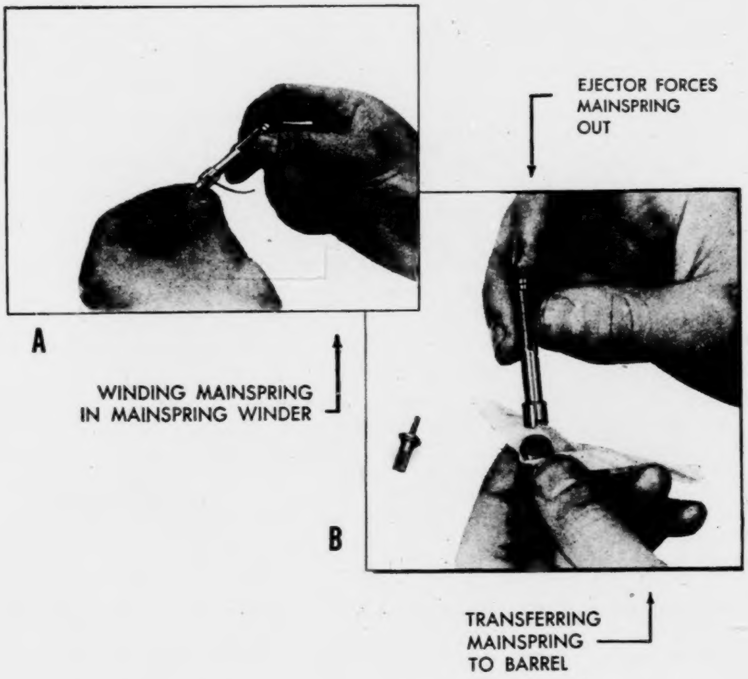
A = arbor diameter in millimeters
B = inside diameter of barrel in millimeters
T = thickness of mainspring in millimeters

Inserting Mainspring in Barrel

Use a mainspring winder for inserting a mainspring into its barrel. If you attempt to feed it into the barrel with your fingers, you may cause damage that will render it unfit for reliable service. Winders are made in different sizes to accommodate various sizes of mainspring barrels. Study parts A and B of figure 6-18, which show the procedure for winding a mainspring into a mainspring winder and for transferring the mainspring to the barrel, respectively.

The procedure for using a mainspring winder follows:

1. Select a proper-size mainspring winder.
2. Check the position of the hook on the arbor to determine the direction for winding the spring. Wind the spring in a reverse direction to the position it will have in its barrel.
3. Attach the inner coil of the mainspring to the arbor of the winder.
4. Wind the spring into the barrel of the winder.


EJECTOR FORCES MAINSPRING OUT
A
WINDING MAINSPRING IN MAINSPRING WINDER
B
TRANSFERRING MAINSPRING TO BARREL

91.180X

Figure 6-18.—Procedure for inserting a mainspring into the barrel.

5. Place the winder over the barrel, with the end of the spring at the hooking end of the barrel. (If it is the tongue-type, the tongue must be bent away from the spring.)

6. Insert mainspring into barrel (part B, fig. 6-18).

7. Lubricate the mainspring and arbor with HEAVY oil. (Pressure between coils of a fully wound spring would force light oil from the spring and cause a binding which would result in uneven power and inaccurate regulation.)

8. Hold the barrel on tissue paper in the left hand and place the cover (held with tissue paper in the right hand) on the barrel, lined up with a scratch mark on the side of the barrel. Then overlap the cover with tissue paper in both right and left hands (to keep finger prints off) and snap the cover on the barrel. If necessary apply force to cover with a brush handle to snap it into place.

9. Remove dirt and fingerprints from the barrel.

MAIN WATCH TRAIN

The main train of a watch is a set of wheels through which the power of the mainspring is transmitted to the escapement. The cogwheel on the mainspring barrel constitutes the FIRST wheel of the train. Because of its position in a watch movement, the second wheel is called the CENTER wheel. The THIRD, FOURTH, and ESCAPE wheels complete the main train. The center, third, and fourth wheels are made of brass, mounted on steel pinions and arbors. The long center wheel arbor projects through the pillar plate and above the dial, to receive the cannon pinion and the hour wheel.

The main train (sometimes called the time train) changes the SLOW motion of the mainspring barrel into FAST motion, causing the cannon pinion carrying the minute hand to make one turn every time the escape wheel makes the required number of beats (18,000 per hour in a pocket watch). Another train, called the dial train, governs the distance the hour hand travels to one turn of the minute hand. In other words, the dial train converts FAST motion to SLOW motion.

Turns of a Pinion

To determine the number of turns a pinion makes, divide the number of teeth in the wheel by the number of leaves in the pinion. For example, if a wheel with 72 teeth meshes with a pinion with 12 leaves, the pinion makes 6 turns for every turn of the wheel ($72 \div 12 = 6$).

Turns of Main Train

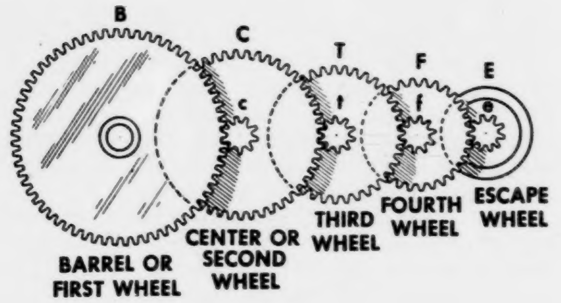
Study figure 6-19. The wheels of the main train are identified by capital letters and the pinions by small letters, as follows:

B = barrel (first wheel)
C = center wheel (second) c = center pinion (second)
T = third wheel t = third pinion
F = fourth wheel f = fourth pinion
E = escape wheel e = escape pinion

A watch train often has the following number of wheel teeth and pinion leaves:

$$\frac{B}{c} = \frac{72}{12} = 6 \qquad \frac{T}{f} = \frac{75}{10} = 7\ 1/2$$

$$\frac{C}{t} = \frac{80}{10} = 8 \qquad \frac{F}{e} = \frac{80}{8} = 10$$



91.181
Figure 6-19.—Main train of a watch.

If you multiply the above quotients (6x8 x 7 1/2 x 10) you get 3,600, the number of turns the escape wheel makes each time the barrel makes a revolution. Divide 3,600 by 6 (number of turns center wheel makes to one turn of barrel) and you get 600, the number of turns the escape wheel makes per hour. These calculations are based on one turn of the center wheel and are represented by this formula:

$$\frac{C \times T \times F}{t \times f \times e} = 600$$

The second hand of a watch is secured to the arbor of the fourth wheel, which means that the fourth wheel makes 60 turns to each turn of the center wheel, as shown by the following formula:

$$\frac{C \times T}{t \times f} = \frac{80 \times 75}{10 \times 10} = 60$$

Most escape wheels have 15 teeth, and each tooth delivers two impulses when the watch is running—the first impulse to the receiving pallet, and the second impulse to the discharging pallet. This means that the escape wheel delivers to the balance wheel twice as many beats as it has teeth. The formula which represents the beats is:

$$\frac{C \times T \times F \times 2 \times E}{t \times f \times e} = \text{Beats per hour, or}$$

in numerical values, it is

$$\frac{80 \times 75 \times 80 \times 2 \times 15}{10 \times 10 \times 8} = 18{,}000 \text{ beats per hour}$$

Number of Teeth in Lost Wheel

Suppose you receive in the instrument shop an unfamiliar watch which has a missing wheel or pinion. How can you calculate the number of teeth in the missing wheel, or leaves in the missing pinion? You can do this by using the following formula: (The fourth wheel, represented by F, is missing.)

$$\frac{80 \times 75 \times F \times 2 \times 15}{10 \times 10 \times 8} = 18{,}000$$

$$225\,F = 18{,}000$$

$F = 80$ (number of missing teeth in fourth wheel)

Suppose we take another example, the problem of finding the number of leaves in a missing third pinion. By using the following formula, with t representing the number of missing leaves, we get:

$$\frac{80 \times 75 \times 80 \times 2 \times 15}{t \times 10 \times 8} = 18{,}000$$

$$\frac{180{,}000}{t} = 18{,}000$$

$$18{,}000t = 180{,}000$$

$t = 10$ (number of leaves in third pinion)

THE ESCAPEMENT

A watch escapement is that unit of the watch which connects the wheel train assembly with the balance wheel assembly. Study the escapement illustrated in figure 6-20. The names and functions of the parts of an escapement are given in the next paragraph. The rest of this section explains the functioning of the escapement, procedures for repairing it, and procedures for manipulating hairsprings used in barometers, dial indicators, watches, and clocks.

ESCAPEMENT TERMINOLOGY

R or RECEIVING STONE—pallet stone which first meets or receives the escape tooth in an escapement action.

L or LET-OFF STONE—pallet stone which last makes contact with the escape tooth.

PALLET ARBOR—the staff on which the pallet swings.

FORK—part located at tail of pallet lever, containing slot which roller jewel enters. The fork delivers the impulse to the roller jewel.

HORNS—circular projections on each side of the fork slot which provide safety action during unlocking and impulse.

ROLLER JEWEL (also called jewel pin)—usually of ruby or sapphire and secured by shellac in a hole in the impulse roller table, the roller jewel is the connecting link between the pallet and the balance wheel.

ROLLER TABLE—flat, circular disk from which the roller jewel is suspended (and in which secured).

DOUBLE ROLLER—roller unit consisting of two metal disks. The upper disk (larger) supports the roller jewel and is known as the impulse roller. The lower disk (smaller) serves as the safety roller. (Has crescent notch.)

CRESCENT—notch in safety roller, to allow the guard pin to pass freely in either direction when the roller jewel is entering the fork.

GUARD PIN—small, brass pin below the fork. This pin serves as a safety device, ensuring that the pallet is in proper position to receive the roller jewel upon its return.

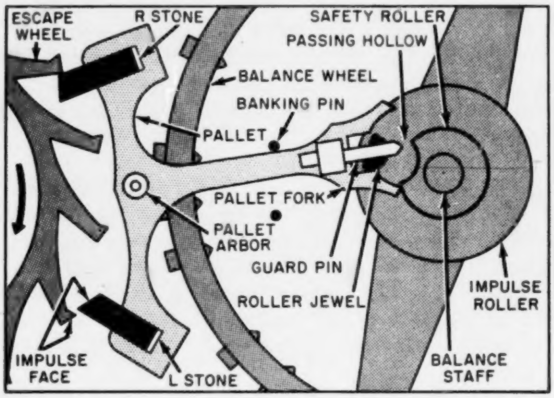
LOCK—amount of overlap between the pallet stone (jewel) and an escape wheel tooth.

LOCKING FACE—side of pallet stone which locks or overlaps a tooth of the escape wheel.

TOE OF TOOTH—corner of escape tooth which locks with the pallet stone.

HEEL OF TOOTH—corner of escape tooth, last part of tooth to leave pallet stone in an escapement action.

LET-OFF CORNER—extreme tip of pallet stone where tooth of escape wheel loses contact with pallet stone.



91.182X

Figure 6-20.—A watch escapement.

BANKING PINS — stops on each side of pallet which control distance pallet may swing.

IMPULSE — beginning at the instant of unlocking, the impulse is the drive of an escape wheel tooth against an impulse face of a pallet stone, causing the pallet to swing to the opposite direction (side). The pallet imparts this motion through roller jewel to the balance wheel.

IMPULSE FACE — inclined plane on the end of the pallet stone on which the escape wheel teeth press to produce the lift in an escapement action. The term impulse face may also refer to the plane on the end of a club tooth of the escape wheel.

DROP — free motion of the escape wheel when one tooth passes the let-off corner of a pallet stone and another tooth locks on the opposite stone.

BANKING TO A DROP — positioning of the banking pin to a point where the escape wheel teeth just clear or let-off the pallets.

DRAW — force exerted by an escape wheel tooth upon the locking face of a pallet stone, tending to bring the pallet lever against the banking pin.

SLIDE — space or distance a pallet stone travels downward on an escape wheel tooth immediately after the tooth comes to a lock with the pallet stone.

PURPOSE OF THE ESCAPEMENT

A watch movement which had only a train of wheels and a mainspring would run for a few moments at full speed when the mainspring was wound. The purpose of the escapement, therefore, is to check the speed of the train, to SLOW IT DOWN. The escapement allows each tooth on the escape wheel to pass at regulated intervals, which are measured and regulated by the balance assembly, without which the escapement could not operate.

The escape wheel, (fig. 6-20) generally made of steel, is the last wheel of the train and is staked on a pinion and an arbor. Power is transferred from the main train by the escape wheel to the pallet. The escape wheel is so constructed that the pallet jewels move in and out between its teeth, allowing only one tooth to escape at a time.

The pallet jewels are set at an angle to make their inside corners reach over three teeth and two spaces of the escape wheel. The outside corners of the jewels reach over two teeth and three spaces of the escape wheel with a small amount of clearance. At the opposite end of the pallet, directly under the center of the fork slot is the guard pin (steel or brass). The fork is the connecting link to the balance assembly.

The escape wheel has 15 teeth and makes 600 revolutions per hour. During a revolution of the escape wheel, each tooth delivers TWO impulses to the pallet, or 18,000 impulses to the balance wheel. This means that the balance wheel vibrates 5 times per second, and that the power of the mainspring is arrested and released every 1/5th second by the locking and unlocking action of a pallet stone with an escape wheel tooth.

HOW AN ESCAPEMENT FUNCTIONS

The following discussion of the operation of an escapement is for one with fixed banking pins, with the roller jewel and both pallet stones correctly located. Before we start this discussion, however, it is best that we explain the meaning of three distinct and different terms used in connection with the roller jewel. These terms are: (1) ROLLER JEWEL FREEDOM, (2) ROLLER JEWEL SHAKE, and (3) ROLLER JEWEL CLEARANCE.

Roller jewel freedom is the difference between the width of the pallet fork slot and the width of the roller jewel. Note the position and the amount of clearance of the roller jewel in figure 6-21.

Roller jewel shake is the space arrangement between the inside corners of the pallet

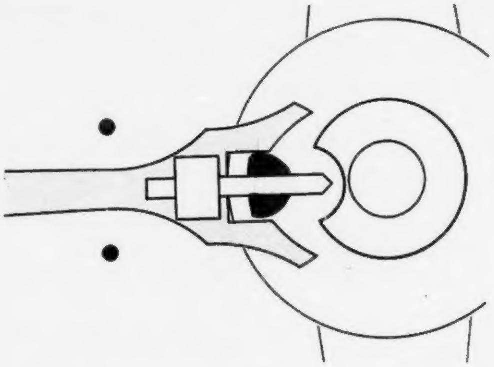


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Figure 6-21. — Roller jewel freedom.

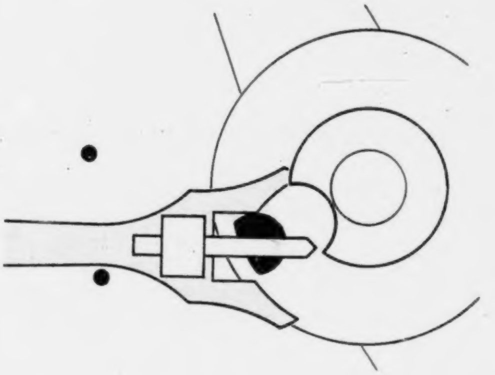

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Figure 6-22.—Roller jewel shake.

fork and the front and back of the roller jewel at the instant of DROP, as shown in figure 6-22.

Roller jewel clearance (sometimes called fork horn clearance) is the clearance for the roller jewel in passing out and past the fork horns. See figure 6-23.

You need to understand the action of the roller jewel, and the procedure for examining this action follows.

Roller Jewel Freedom

Select a good loupe and examine the action of an escapement. Move the balance wheel slowly with the index finger until the roller jewel enters the fork slot. Note that this movement unlocks the escape wheel tooth. At the instant of unlocking of the tooth, the impulse action begins, as illustrated in figure 6-24.

Next, turn the balance wheel slowly enough to enable you to observe the travel of the escape wheel tooth across the pallet stone (fig. 6-25).

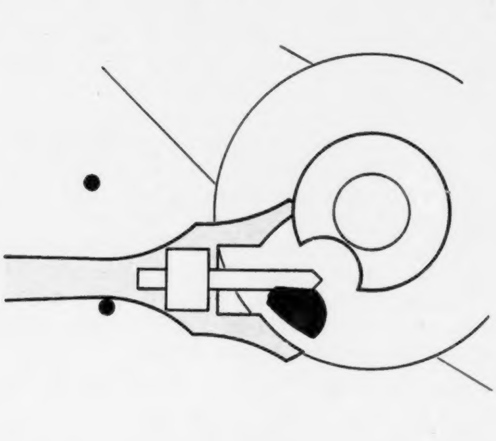

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Figure 6-23.—Roller jewel clearance.

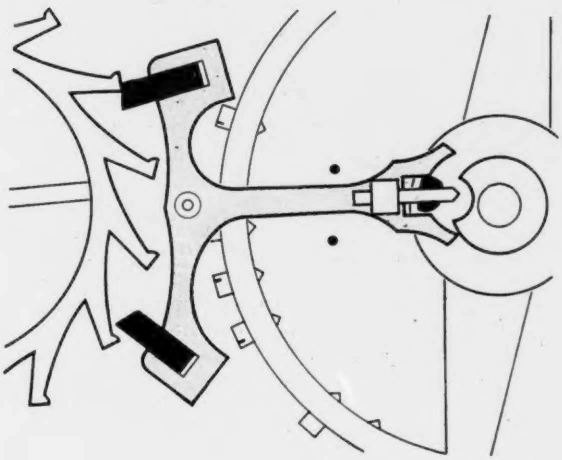

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Figure 6-24.—Unlocking of an escape wheel tooth.

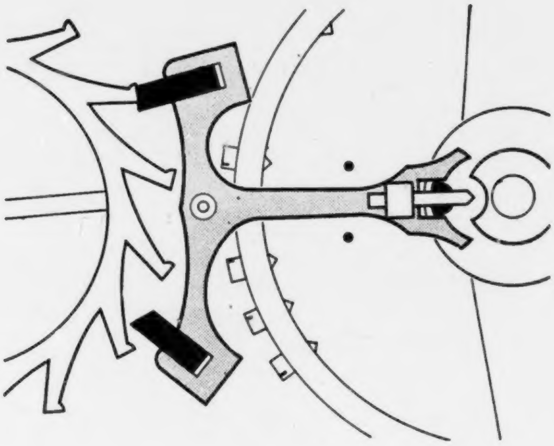

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Figure 6-25.—Slide of escape wheel tooth across a pallet stone.

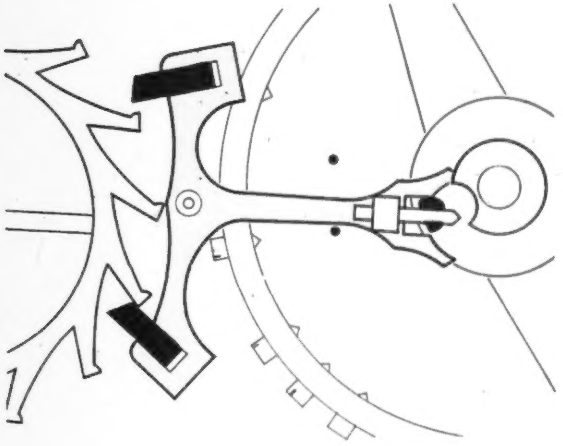

Figure 6-26.—Drop and lock of escape wheel teeth. 91.188X

Observe the position of the roller jewel while the slide is taking place. At the exact instant of the drop of the tooth from the pallet stone another tooth LOCKS on the other pallet stone (fig. 6-26).

Roller Jewel Shake

By stopping the motion of the balance wheel at the exact instant of the LOCK and the DROP, you can check for roller jewel shake. Move the fork back and forth with an escapement trying tool or a pivot broach. This action causes corner A (fig. 6-27) of the fork slot to touch the back side of the roller jewel and corner B to touch the flat face of the roller jewel. The fork has not yet touched the banking pin.

Now, reverse the motion of the balance wheel, to allow the roller jewel to move the fork enough to unlock the escape wheel tooth. The impulse now begins; and when it is completed, the drop occurs, at which time the escape wheel again comes to lock. Study this action in parts A, B, and C of figure 6-28.

At this point, recheck for roller jewel shake. Observe that the shake is equal on both sides, indicating that the fork moves as far on one side of the center line as on the other side.

Roller Jewel Clearance

After you check the escapement for roller jewel shake, examine the CLEARANCE of the roller jewel as is completely passes out of the fork slot. Turn the balance wheel slowly with the index finger and observe the roller jewel as it gradually passes out of the fork slot and past the fork horn.

As the roller jewel passes the fork horn, check for clearance. Study figure 6-29, which shows the fork against the banking pin at A and the amount of clearance between the roller jewel and the fork horn.

Guard Pin Shake

Guard pin shake is the distance between the guard pin and the safety roller when the fork rests against the banking pin. This distance should be SLIGHTLY LESS than the lock.

Check for guard pin shake after the roller jewel passes out of the fork slot and beyond the fork horn. See figure 6-30, which shows the roller jewel completely out of the fork and the guard pin pressed against the safety roller. The escape wheel tooth is still safely locked on the pallet stone. Note that the fork is NOT against the banking pin. When it does touch the banking pin, there will be a little space between the guard pin and the safety roller.

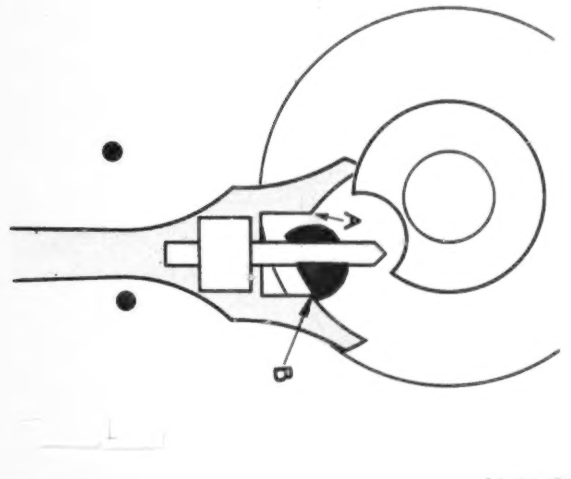

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Figure 6-27.—Checking roller jewel shake.

Checking the Draw

The function of the draw (draft) on the pallet stone and the escape wheel teeth is to hold the fork securely against the banking pin during the passage of the roller jewel from the fork slot.

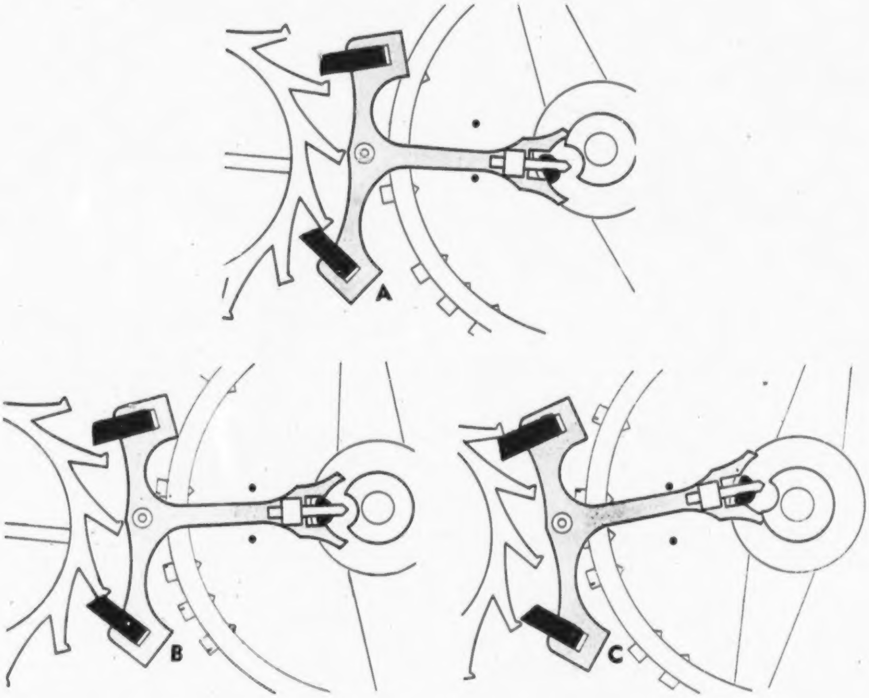

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Figure 6-28.—Checking roller jewel shake (with motion of balance wheel reversed).

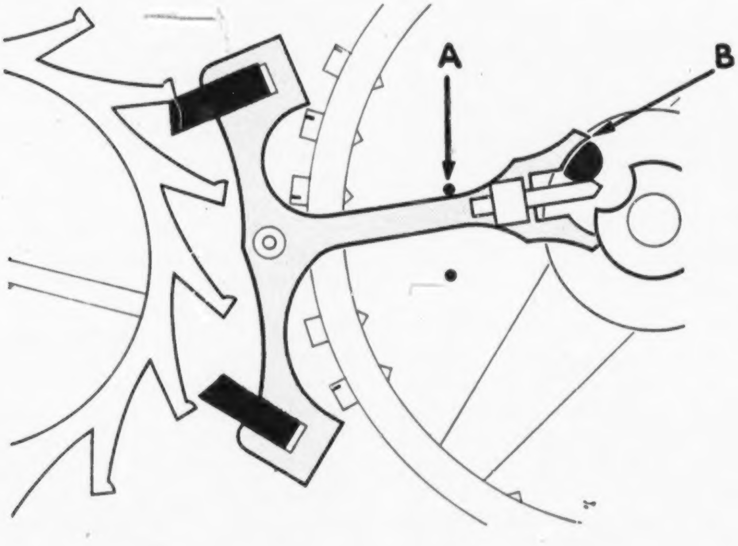

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Figure 6-29.—Checking roller jewel clearance.

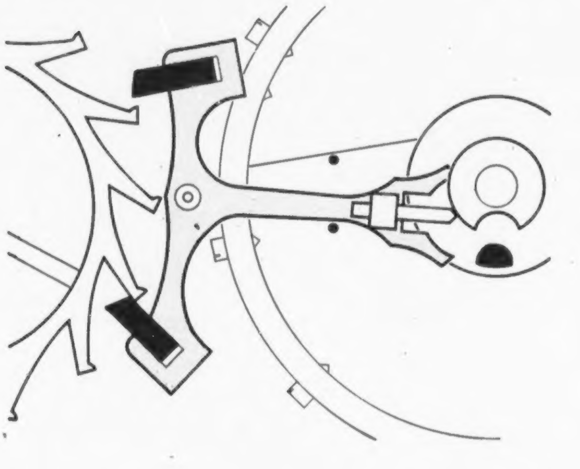

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Figure 6-30.—Checking guard pin shake.

Check the draw at the SAME TIME you test for guard pin shake. When the guard pin touches the safety roller, quickly release the fork and the draw will start. It will immediately pull the guard pin away from the roller and hold the fork against the banking pin.

Testing the Slide

The space a pallet stone travels DOWNWARD on an escape wheel tooth after the lock occurs is called THE SLIDE. Test the slide of the pallet stone on an escape wheel tooth by quickly moving the roller jewel away from the position where you checked the roller jewel shake, and AWAY form the LINE OF CENTERS.

Banking to a Drop

BANKING TO A DROP is another method for checking a watch escapement, based entirely on movable banking pins with which millions of watches were originally provided. Because many of these watches are still in use, it is essential that you understand the meaning of BANKING TO A DROP, which can be considered as the basic reference for checking the LOCK, DROP, ROLLER JEWEL SHAKE, and GUARD PIN SHAKE. Make the tests in the following order:

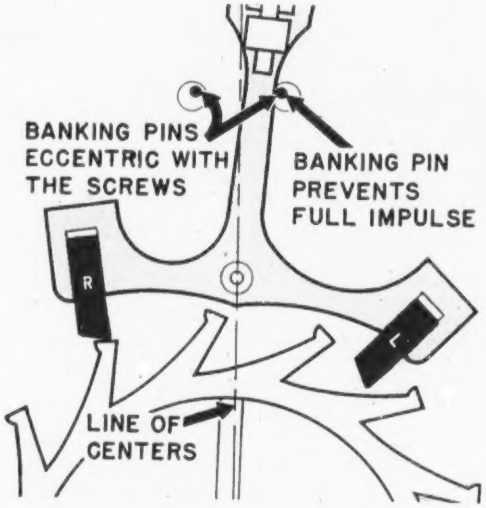

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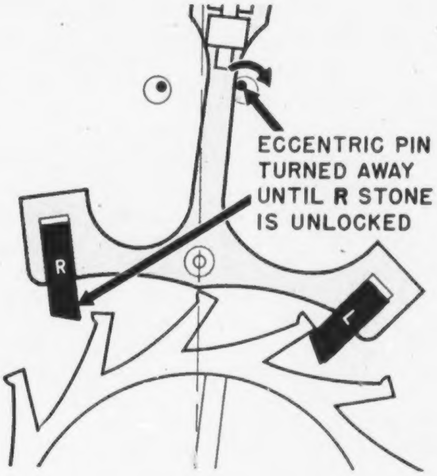
Figure 6-31.—First step in banking to a drop.

1. Remove the balance wheel and turn the L banking pin as close as possible to the LINE OF CENTERS. The fork now rests against the L banking pin, held by the power of the mainspring transmitted through the main train to the impulse faces of the escape wheel teeth and the pallet stones. See figure 6-31.

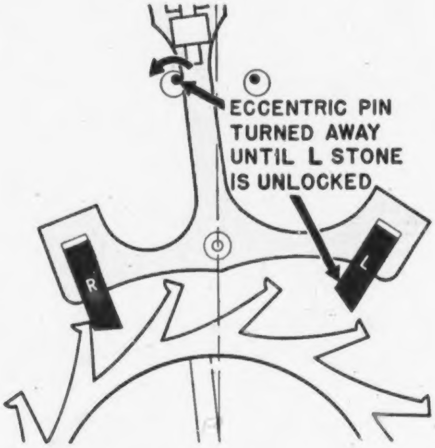
2. With the watch held DIAL DOWN in the left hand, turn the screw against which the fork rests away from the line of centers.

3. With a good loupe, observe the movement of the impulse face of the escape wheel tooth across the impulse face of the pallet stone. As soon as the impulse face of the escape wheel tooth drops off the R pallet stone, another tooth locks itself on the L stone. The lock is about 1/4 the width of the impulse face of the pallet stone. (You are interested in the AMOUNT OF LOCK just after an escape tooth loses contact with a pallet stone.) Turn the eccentric banking pin screw JUST ENOUGH to allow a tooth to escape a pallet stone (fig. 6-32). Bear in mind that the location of the banking pins is determined by the position of the pallet stones. The farther OUT the pallet stones are, the farther AWAY from the line of centers must the eccentric banking pin be moved before a tooth escapes.

4. Turn the R banking pin so that it is as close as possible to the line of centers. The


ECCENTRIC PIN
TURNED AWAY
UNTIL R STONE
IS UNLOCKED
R
L

61.72.2X
Figure 6-32.—Second step in banking to a drop.

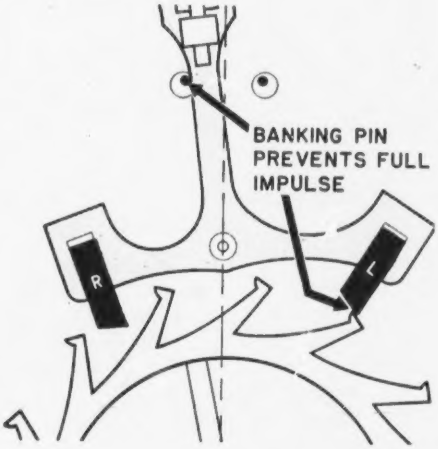

ECCENTRIC PIN
TURNED AWAY
UNTIL L STONE
IS UNLOCKED
R
L

61.72.4X
Figure 6-34.—Fourth step in banking to a drop.

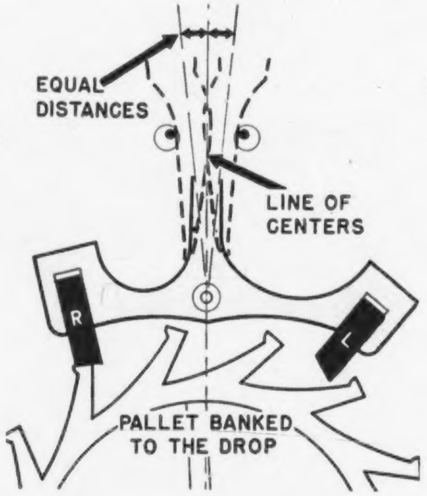
fork must be moved so that it rests against the R banking pin, as illustrated in figure 6-33.

5. Now turn the screw for the R banking pin just enough to allow the escape wheel tooth to drop off the L pallet stone (fig. 6-34). The fork must then be moved back and forth until the escape wheel makes one complete turn. The pallet may now be considered as BANKED TO THE DROP. When this is so, the fork moves an equal distance from each side of the line of centers (fig. 6-35).

6. From here on, with the balance wheel and hairspring unit in the watch, check the lock, drop, roller jewel shake, and guard pin shake as you did for a watch with fixed banking pins. Guard pin shake at this point is barely


BANKING PIN
PREVENTS FULL
IMPULSE
R
L

61.72.3X
Figure 6-33.—Third step in banking to a drop.


EQUAL
DISTANCES
LINE OF
CENTERS
R
L
PALLET BANKED
TO THE DROP

61.72.5X
Figure 6-35.—A watch pallet banked to a drop.

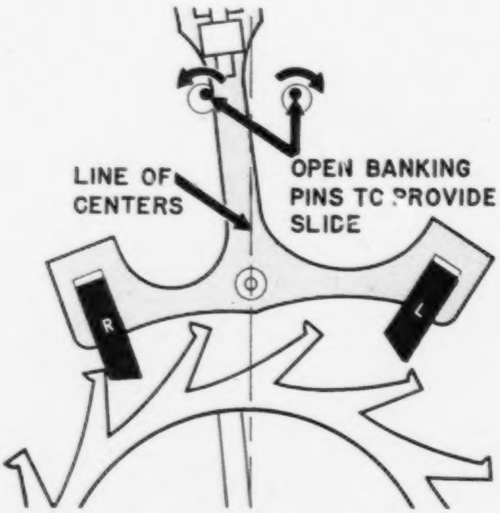
noticeable, not more than 1/2 degree in a light lock. As the lock is increased, more guard pin shake is permissible, as much as 1 degree.

7. When the lock, drop, guard pin shake, and roller jewel shake are satisfactory, turn both banking pins away from the line of centers to check THE SLIDE. Study figure 6-36. Turn the pins just enough to allow an increase of about 1/3 the lock established when banking to a drop. You will now find that guard pin shake has been slightly increased on both sides.

Turn the balance wheel carefully with the index finger and observe the slide. Immediately after the drop, as you turn the balance farther away from the line of centers, the pallet jewel moves down (slides) a short distance on the escape wheel tooth. Slide is present on each tooth of the escape wheel.

REPAIRING THE ESCAPEMENT

On occasions, you will have the responsibility for repairing or replacing major parts (escape wheel, pallet, and roller) of an escapement. This section takes into consideration the procedure for doing this work, and it also explains how to position the pallet stones in order to have the escapement function properly.



61.72.6X

Figure 6-36.—Checking the slide.

The tools you need for repairing an escapement are shown in figure 6-37.

Replacing a Roller Jewel

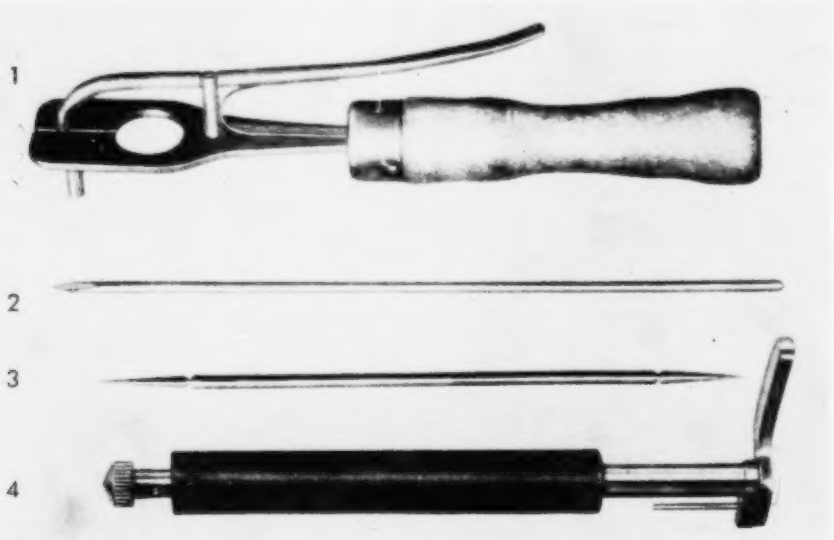
The procedure for installing a new roller jewel is as follows:

1. Check the size of the jewel in the fork of the pallet. A jewel too large will not fit, of course, and a jewel too small causes lost motion of the pallet. There should be a roller jewel clearance (freedom) of .01 mm. for small watches, and .03 mm. for 16-size watches. A roller jewel must also have correct length, as shown in figure 6-38.
2. Thoroughly clean the roller jewel hole with alcohol, so that shellac will adhere to its surface (all round).
3. Use tweezers to insert the roller jewel into the hole in the roller. To prevent breakage of the jewel, be careful about the amount of pressure you exert on the tweezers.
4. Place the roller (with or without balance wheel attached) in the jewel pin warmer and heat the warmer over an alcohol lamp. Study figure 6-39.
5. As the pin warmer is heating over the alcohol lamp, apply a piece of string shellac on top of the impulse roller, directly over the jewel (fig. 6-39). At this point, make certain that the jewel is perpendicular to the roller (before it sets).
6. Dip a piece of pegwood in alcohol and remove the excess shellac.
7. After the shellac has had time to harden around the jewel, put the balance assembly in the watch and check its action with the fork of the pallet.

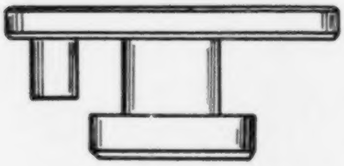
Installing a Pallet Arbor

Pallet arbors are of two types, friction-fitted and screw. To remove or to install a friction-fitted arbor, use a staking punch, as shown in figure 6-40. Note the size of the hole in the flat-faced punch, and also the size of the hole in the stump. The hole in the punch should be slightly larger than the pivot rests on the shoulder of the arbor.

The pallet is usually positioned slightly below the upper pivot of the arbor, but it can be shifted to any height.



91.193X
Figure 6-37.—Tools used for repairing an escapement.



91.194X
Figure 6-38.—Proper length for a roller jewel.

A screw-type pallet arbor (fig. 6-41) is threaded on its upper shoulder and can be screwed into the pallet. Figure 6-41 shows how the arbor can be screwed in or out with a pin vise. Observe that the pin vise is secured to the lower shoulder of the arbor.

Fitting a New Guard Pin

Remove the old guard pin in the manner illustrated in figure 6-42. Cut off the small end and then push it out with a pair of pliers or tweezers.

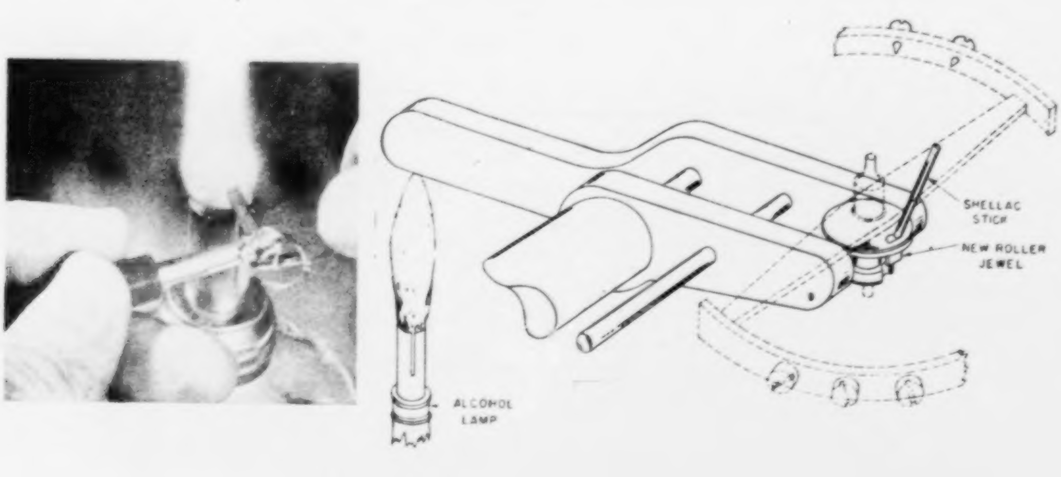
Insert a new guard pin in the opposite direction; that is, from the pallet side. Force the pin friction-tight with a pair of tweezers. If you do not have a new guard pin available, insert a piece of thin brass wire into a pin vise and roll-file it on a boxwood slip to a fine taper. Then burnish the pin.

After you have inserted the new pin, clip it off with pliers. Allow just enough length for finishing. Finish the tip of the pin with an oilstone slip in the manner shown in figure 6-43. The point of the pin should be so filed that it makes a 90° angle, as illustrated.

Now test the pallet in the watch. If the guard pin shake is excessive, lengthen the pin by pressing the thick end closer to the fork. If the pin is too long, use an oilstone slip to shorten it, still retaining the 90° angle on the end.

Straightening the Pallet Lever

You can straighten a bent pallet lever by placing the pallet on a boxwood slip, with the arbor inserted in a hole, and striking the bent shank with tweezers until you have it in its

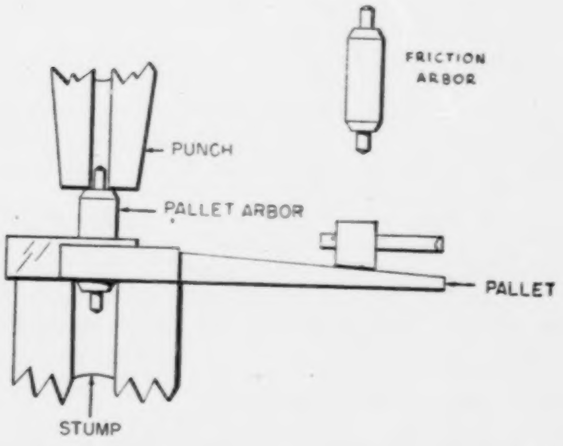

SHELLAC STICK
NEW ROLLER JEWEL
ALCOHOL LAMP

91.195X
Figure 6-39.—Inserting a roller jewel.

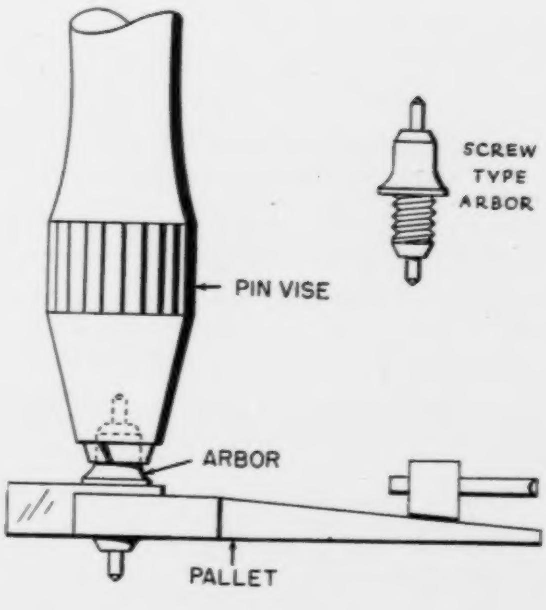
original level condition. Study the procedure for doing this in figure 6-44.

Moving Pallet Stones

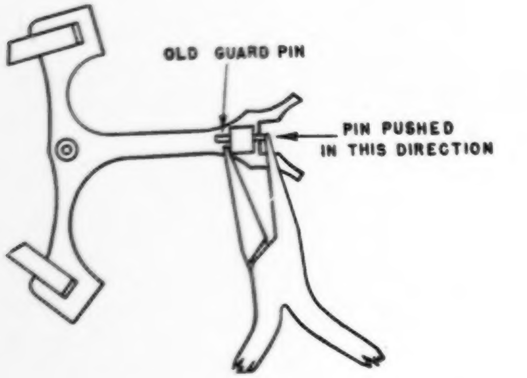
If one pallet stone is moved OUT (toward an escape wheel tooth), it causes the pallet fork to swing a greater distance from the line of centers before the lock occurs on the opposite stone. If one pallet stone is moved IN (away from an escape wheel tooth), the distance the


FRICTION ARBOR
PUNCH
PALLET ARBOR
PALLET
STUMP

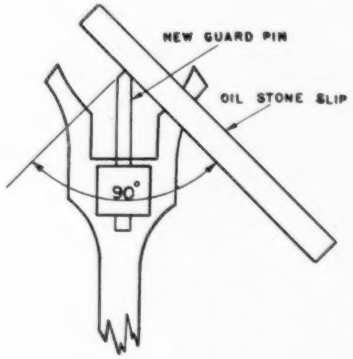
91.196X
Figure 6-40.—Replacing a friction type pallet arbor.


SCREW TYPE ARBOR
PIN VISE
ARBOR
PALLET

91.197X
Figure 6-41.—Installing a screw-type pallet arbor.



91.198X
Figure 6-42. — Tilting a new guard pin.



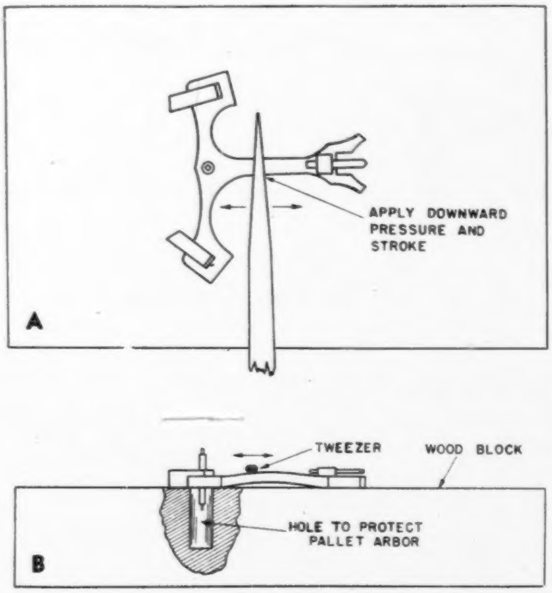
91.199X
Figure 6-43. — Putting a 90° angle on a guard pin point.

pallet swings from the line of centers before locking with the other stone is reduced.

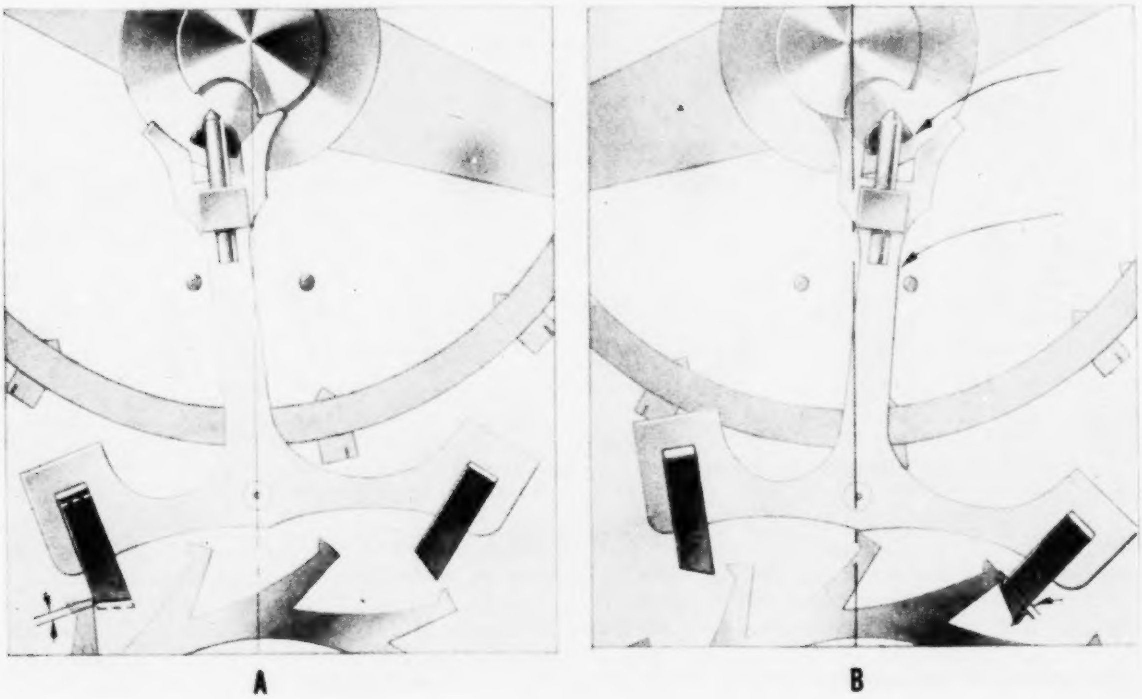
Because the movement of a pallet stone affects the distance the pallet moves, when one stone is moved OUT or IN (causing the lock to be increased or decreased) the lock on the opposite stone is increased or decreased by the same amount. For example, if you move the R stone out a small amount, you increase the lock on the L stone the same amount. At the same time, the pallet moves closer to the L banking pin at the instant of lock, permitting less slide. See figure 6-45.

When you must move a pallet stone out or in, proceed as follows:

1. Remove the pallet from the watch and place in upside down on a pallet warmer, with the lower pivot placed in the hole provided in the movable arm.
2. Warm the shellac holding the pallet stones by heating the pallet warmer over an alcohol lamp. CAUTION: Overheating causes shellac to spoil.
3. Remove the pallet warmer from the lamp, and remove the pallet stone(s) in or out with a nickel or brass tool (fig. 6-37).
4. Remove the pallet from the warmer. Lift straight up in order to keep the stones level with the body of the pallet.
5. Dip a piece of pegwood in alcohol and remove the excess shellac.
6. Replace the balance wheel in the watch and determine the amount of travel of the pallet from the line of centers by testing the roller jewel shake. If the distance of the pallet from the line of centers is greater than before at the instant of lock; the roller jewel shake has increased. If the pallet is closer to the line of centers at the instant of lock, the roller jewel shake has decreased.


APPLY DOWNWARD PRESSURE AND STROKE
A
TWEEZER
WOOD BLOCK
HOLE TO PROTECT PALLET ARBOR
B

91.200X
Figure 6-44. — Straightening a pallet lever.



91.201X

Figure 6-45.—How the moving of a pallet stone affects lock and slide.

PALLET STONE RULE: If the lock is TOO LIGHT, pull OUT the stone opposite the LESSER jewel pin shake. If the lock is TOO STRONG, push IN the stone opposite the GREATER jewel pin shake.

HAIRSPRING MANIPULATION

The word MANIPULATION, when used in connection with hairsprings, refers to such things as: (1) determining the strength of a hairspring, (2) pinning a hairspring in a collet, (3) overcoiling a hairspring, (4) vibrating a hairspring, and (5) truing a hairspring.

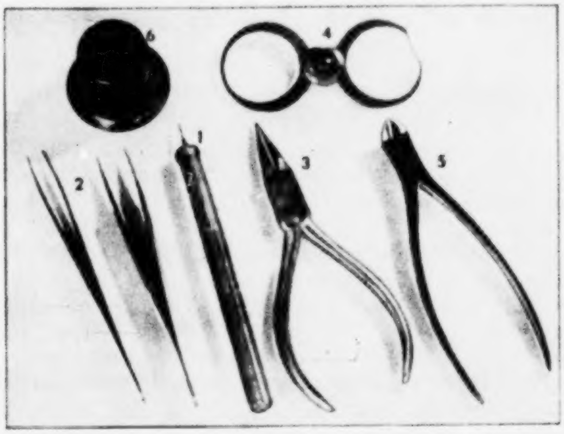
You must be able to true a hairspring in the flat and in the round. To do so, you must first learn the basic principles for manipulating hairsprings. Through actual experience in Navy instrument shops, you will learn how to accomplish all phases of hairspring manipulating.

COLLETING

The inside coil of a hairspring must be attached to a collet which fits snugly on the top shoulder of the balance staff. The procedure for doing this is known as COLLETING. Colleting is delicate work which requires skillful use of proper tools: colleting arbor (tool for holding the collet), 3-power loupe, pair of cutting pliers, pair of long-nose pliers, pair of regular over-coiling pliers, and two pairs of fine steel tweezers. These tools are illustrated in figure 6-46. CAUTION: Some Instrumentmen like to use a high-power loupe for doing this work, but continual use of such a loupe causes eye strain.

Removal of Inner Coils

The first principal step in colleting is the removal of as much of the inner end of a hairspring as is necessary to make room for the



1. Colleting arbor.
2. Tweezers.
3. Snipe-nose pliers.
4. Hairspring-truing calipers.
5. Side-cutting pliers.
6. Loupe

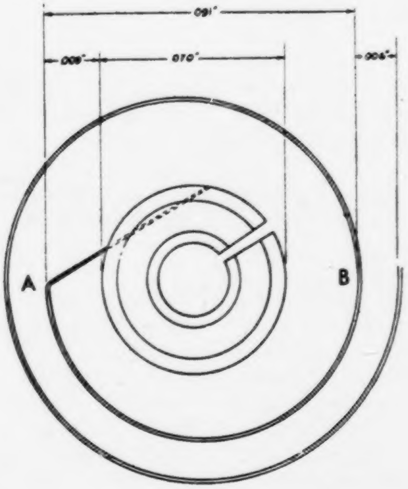
1.21X
Figure 6-46.—Tools used in manipulating hairsprings.

collet. This means that you must break out an inner coil(s) of the hairspring.

When a collet is placed in the center of a hairspring, the space from the edge of the collet to the first inner coil is 1 1/2 times as great as the space between any other coils in the spring. For example, if the collet diameter is 0.070 inch, which is true of the collet shown in figure 6-47, and the space between the coils is 0.006 inches, the distance between point A and point B should be 0.091 inch. Note that the distance between point B and the second coil is 0.006 inches, and that the distance between the collet and point A is 0.009 inches. This means that this collet is correctly positioned in the middle of the hairspring.

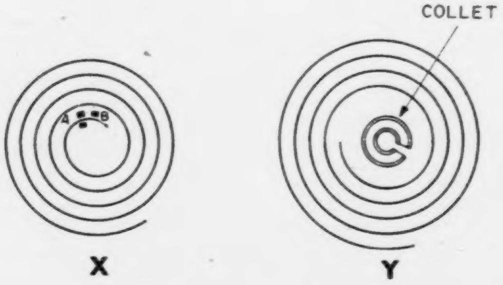
To break out the inner coils of a hairspring, proceed as follows:

1. Measure the diameter of the collet.
2. Measure the distance between coils in the spring.
3. Select a spot on a coil where the distance between the spot and the collet is 1 1/2 times the distance between any two coils of the spring.



91.202X
Figure 6-47.—Inner coil dimensions of a hairspring.

4. With a pair of tweezers, grasp the coil at the selected spot and exert enough pressure to prevent slippage. See A in part X of figure 6-48.
5. With another pair of tweezers, grasp the coil to be broken at point B (part X, fig. 6-48) and pull out as far as necessary to break it. Another way to break the coil is to bend it back and forth.
6. Put the collet back in the middle of the hairspring and check measurements for accuracy (part Y, fig. 6-48).



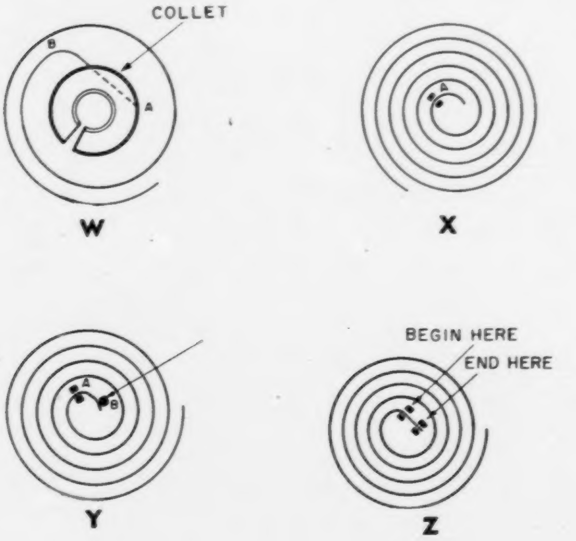
91.203X
Figure 6-48.—Procedure for breaking out the inner coil.

Forming the Tongue

The SECOND STEP in colleting is making the tongue, which is that portion of the inner coil (line AB in part W of fig. 6-49) which fits in the pin hole in the collet.

The following procedure for forming a tongue on the inner coil of a hairspring is recommended:

1. Lay the hairspring flat on a bench.
2. Grasp the inner coil with a pair of tweezers at point A (part X, fig. 6-49).
3. With a second pair of tweezers, grasp the end of the coil at B (part Y, fig. 6-49) and bend the coil in the direction indicated by the arrow. Avoid a sharp bend at point A. With experience, you will learn the CORRECT AMOUNT of bend to put on the coil at this point.
4. Straighten the tongue by grasping it with one pair of tweezers at the point indicated by BEGIN HERE in part Z of figure 6-49 and by straightening it out gradually with another pair of tweezers between the BEGIN HERE and END HERE points. Use gentle pressure with the second pair of tweezers, and pinch and pull on the coil until you have it perfectly straight. This is not a difficult task, but it does require care.



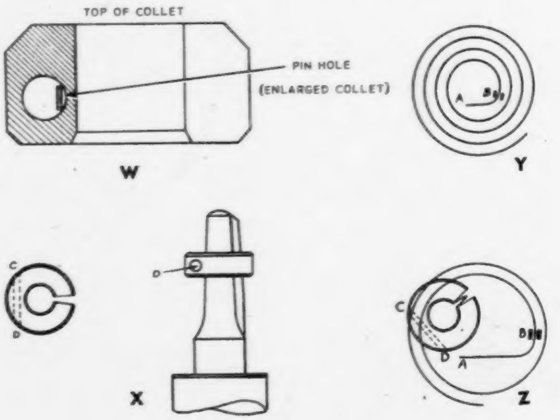
91.204X

Figure 6-49.—Forming the tongue of a hairspring.

Pinning-In

Pinning-in is the process of fastening the hairspring to the collet. The procedure for doing this follows:

1. Place the collet on a colleting arbor with the top of the collet facing up and the pinhole facing you. Study parts W and X of figure 6-50.
2. Grasp the inner coil with a pair of tweezers just back of the bend made to form the tongue (B in part Y, fig. 6-50) and bring the spring down over the top of the colleting arbor, with the tongue in direct line with the collet pin hole (D in part X, fig. 6-50).
3. Grasp the colleting arbor with the left hand and turn it counterclockwise to the extent necessary to bring the pin hole of the collet into direct line with the hairspring tongue (part Z, fig. 6-50).
4. Hold the collecting arbor firmly with the left hand and insert the tongue in the pin hole. Use the thumb and first finger of the right hand to support the hairspring and to prevent if from tipping. CAUTION: Do NOT distort coils in the spring.



91.205X

Figure 6-50.—Inserting hairspring tongue in a collet.

5. Grasp the big end of a tapered brass pin with a pair of tweezers and insert it in the collet pin hole at D (fig. 6-51). Push the pin in tight enough to hold it in position.

6. Measure the distance between the collet and point B (fig. 6-51), and also the distance between point B and the second coil in the spring. If the distance between B and the collet is 1 1/2 times the distance between B and the second coil, the tongue is correctly pinned in the collet hole.

7. If the tongue is not correctly pinned, loosen the metal pin sufficiently to enable you to move the tongue IN or OUT, as necessary. Your measurements must be accurate.

Tightening Pin in Collet

The procedure for tightening the tapered metal pin in the collet hole is as follows:

1. With a pair of snipe-nose pliers, grasp the small end of the tapered pin and pull it tight, using a pulling and twisting motion. Study figure 6-52.

2. Turn the colleting arbor in a clockwise direction until you have formed a 90° bend in the pin (fig. 6-53 top.)

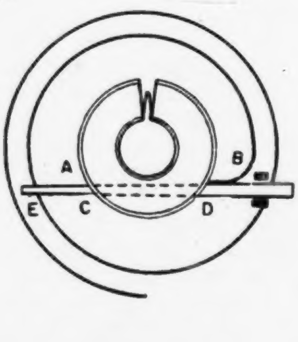
3. Turn the arbor in a counterclockwise direction until the pin breaks off. (fig. 6-5 bottom.)

4. To break off the large end of the colleting pin, make the 90° bend by turning the arbor in a COUNTERCLOCKWISE direction and break the pin off by turning the arbor in a CLOCKWISE direction.

Before you remove the collet and hairspring from the colleting arbor, make a check to determine whether: (1) both ends of the colleting pin are broken off cleanly at the collet, (2) the pin is tight in the collet hole, and (3) any inside coils are bent or distorted. CAUTION: If inside coils are bent or distorted in any manner, discard the spring.

Staking Collet on Balance Staff

The five steps discussed next are recommended for staking a collet on a balance staff. Use a staking stand.



91.206X
Figure 6-51. — Pinning hairspring tongue in a collet.

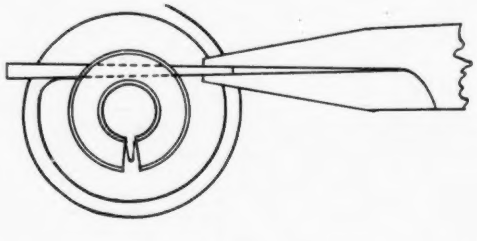


Figure 6-52. — Tightening the brass pin in a collet. 91.207X

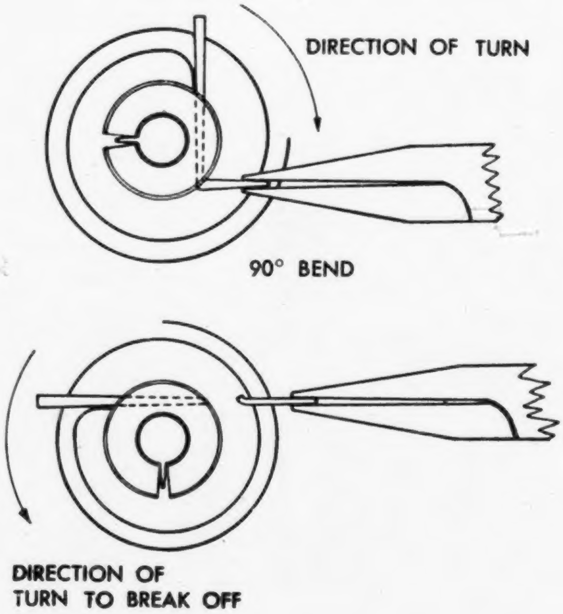
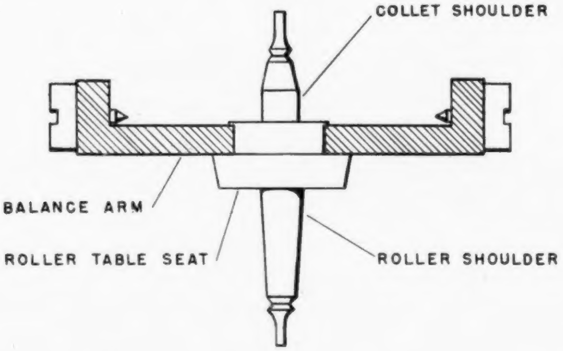
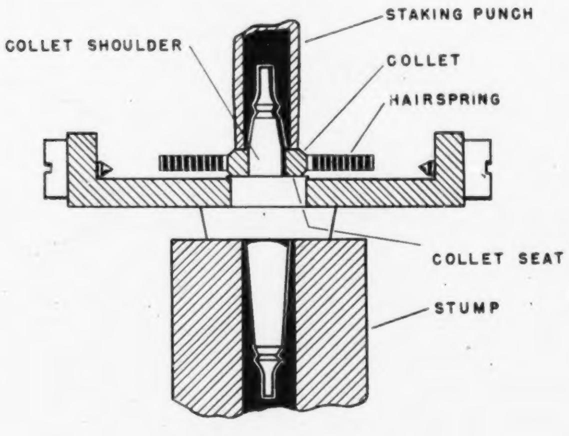


Figure 6-53.—Breaking off the ends of a colleting pin. 91.208X



91.209X
Figure 6-54.—Nomenclature of a balance assembly.

1. Select a stump with a hole slightly larger than the roller shoulder of the staff, but smaller than the roller table seat (fig. 6-54).
2. Place the selected stump in the staking table and insert the balance staff in the stump, as shown in figure 6-55.
3. Select a staking punch with a hole slightly larger than the collet shoulder of the balance staff, but smaller than the outside diameter of the collet (fig. 6-55).
4. Lay the hairspring and collet on the balance staff with the top side of the collet up, and position the spiral of the spring counterclockwise from the pinning point.
5. Bring the staking punch down on the collet and gently force the collet onto the collet shoulder to seat it firmly. Study figure 6-55. The friction between the collet and the collet shoulder must always be sufficient to hold the spring in place.



91.210X
Figure 6-55.—Collet forced into position with a staking punch.

When you finish the staking process, dip the entire assembly in a good cleaning solution and properly rinse it. Next, dip the assembly in alcohol and dry it in a box containing wood sawdust. Then put the balance unit in calipers and remove small particles of sawdust with a camel's hair brush.

HAIRSPRING TRUING

Hairspring truing is the procedure of locating the collet so that it is flat and exactly in the center of the coils of a hairspring. This operation is necessary to correct errors resulting from the breaking out of coils, forming the tongue, and pinning the tongue in the collet hole. Attaching the hairspring to the collet requires so much skill that it is almost impossible to do it without the introduction of errors. The following discussion tells you how to locate and how to eliminate these errors. There are generally two types of errors in a hairspring: (1) errors in the round, and (2) errors in the flat. These are discussed separately.

Errors in the Round

To check a hairspring for errors in the round, secure the balance wheel and hairspring in calipers in the manner illustrated in figure 6-56 and observe the action of the spring as you slowly rotate the balance wheel with the side of the index finger. If the first three or four inside coils appear as perfect circles, the hairspring is TRUE IN THE ROUND. If the coils seem to jump or describe irregular circles as the balance wheel rotates, there is an ERROR IN THE ROUND.

Turn now to figure 6-57 and check some hairsprings which have erros in the round. The first part of this illustration shows a hairspring which is true in the round, so compare all the other hairsprings in the illustration with this one. The type of error for each hairspring is listed beneath it. Pay particular attention to the DEGREE OF ERROR IN THE ROUND in each hairspring.

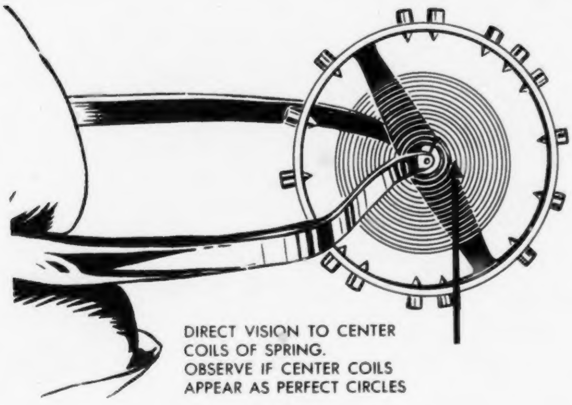


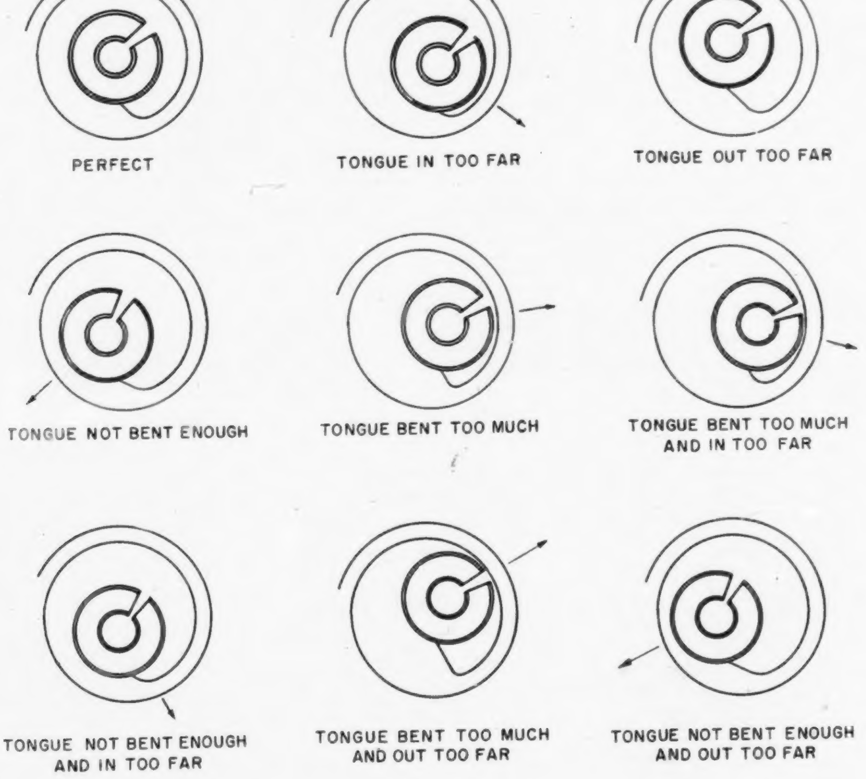
Figure 6-56.—Checking hairspring for errors in the round. 91.211X

After you locate errors in the round in a hairspring, your next task is to eliminate them by bends properly made in the coils of the hairspring. You can make these bends while the balance wheel is supported in calipers. Make them on the 1/8th part of the first coil near the elbow of the bend made to form the tongue.

Study next figure 6-58, which shows the procedure for correcting an error in the round as a result of the tongue's having been INSERTED IN TOO FAR in the collet hole. To correct this error, do the following:

1. Grasp the inside coil with tweezers at point A (part X, fig. 6-58) and bend by coil AWAY from the collet, as indicated by the arrow.

2. Grasp the inside coil at point B (part Y, fig. 6-58) and bend the coil TOWARD the


PERFECT

TONGUE IN TOO FAR

TONGUE OUT TOO FAR

TONGUE NOT BENT ENOUGH

TONGUE BENT TOO MUCH

TONGUE BENT TOO MUCH AND IN TOO FAR

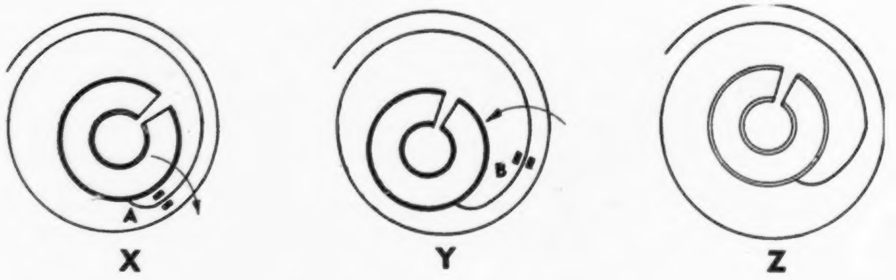
TONGUE NOT BENT ENOUGH AND IN TOO FAR

TONGUE BENT TOO MUCH AND OUT TOO FAR

TONGUE NOT BENT ENOUGH AND OUT TOO FAR

91.212X

Figure 6-57.—Typical hairspring errors in the round.



91.213X

Figure 6-58.—Correction of an error in the round (tongue inserted in too far).

collet. When you finish with this bend, the position of the collet with respect to the coils of the spring should be as indicated in part Z of figure 6-58.

If you pin the tongue of a hairspring TOO FAR OUT of the collet, the hairspring will have an error in the round. Make correction by bending the inner coil in the manner described in the next two steps.

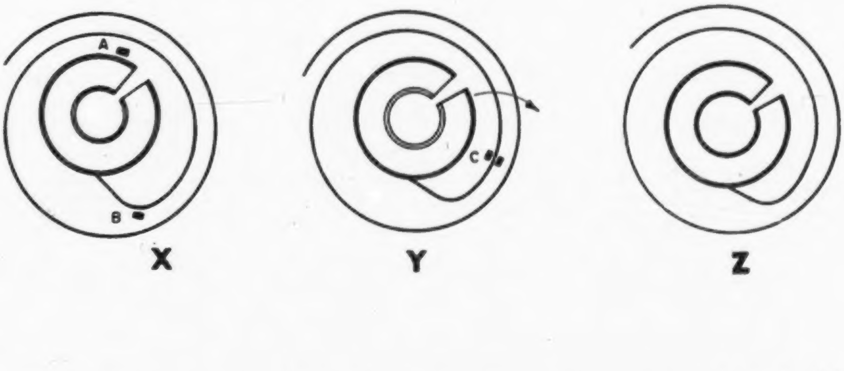
1. Place the tweezer points on the collet and the elbow of the tongue at the spots indicated by A and B in part X of figure 6-59 and gently squeeze IN on the coil at point B, as indicated by the arrow.

2. Grasp the inside coil at point C (part Y, fig. 6-59) and bend the coil AWAY FROM the collet. Part Z of figure 6-59 shows the results of your bending.

On occasions, an error in the round of a hairspring is caused by NOT BENDING THE TONGUE ENOUGH AT THE ELBOW. You can correct such an error by grasping the inside coil with a pair of tweezers at point A (part Y, fig. 6-60) and by bending the coil TOWARD THE COLLET. Correction of this error is illustrated in part Z of figure 6-60. If you bend the tongue TOO MUCH at the elbow, you can make correction by grasping the inner coil at the same point as just explained and by bending it AWAY FROM THE COLLET.

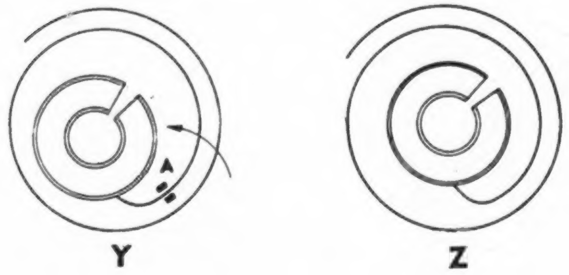
At times, you may bend the tongue TOO MUCH and also pin it in TOO FAR. This is a double error you can correct by making two bends:

1. Grasp the inside coil with tweezers at point A, illustrated in part X of figure 6-61, and bend the coil AWAY FROM THE COLLET.



91.214X

Figure 6-59.—Correction of an error in the round (tongue pinned too far out).



91.215X
Figure 6-60.—Correction of an error in the round (tongue not bent enough at elbow).

2. Grasp the inside coil at B (part Y, fig. 6-61) and bend the coil TOWARD THE COLLET, as indicated by the arrow. After you properly manipulate the hairspring to correct this error in the round, its position relative to the collet is as illustrated in part Z of figure 6-61.

Other errors in the round can be corrected by making bends on the inner coil next to the elbow at the CORRECT SPOTS and in the PROPER AMOUNT. With practice, you will learn how to correct all types of errors in the round. Procedures for doing the work are essentially the same for all types of hairsprings.

ERRORS IN THE FLAT

A balance wheel and hairspring are shown in figure 6-62 in the correct position in calipers for checking errors in the flat. The horizontal plane of the hairspring should be parallel with the horizontal plane of the collet.

Six major errors in the flat may be introduced into a hairspring by the colleting process, as follows:

1. The point of the tongue, represented by A in figure 6-63, may be bent downward in relation to the spiral portion of the spring. If this condition exists, all coils of the spring are HIGH opposite the pinning point.
2. The end of the tongue may be bent upward (fig. 6-63), causing all coils of the spring opposite the pinning point TO BE LOW.
3. The flat face of the tongue MAY NOT BE FIXED in a vertical position.
4. The flat face of the tongue MAY BE FIXED AT AN ANGLE.

When condition 3 or 4 exists, the spiral portion of the spring is HIGH or LOW, 90° from the pinning point.

5. The end of the tongue may be fixed TOO LOW in the pin hole of the collet, causing all coils to be HIGH opposite the pinning point.
6. The end of the tongue may be fixed TOO HIGH in the collet hole, causing all coils to be LOW opposite the pinning point.

After you true a hairspring in the flat, check it again for errors in the round. Then recheck it for errors in the flat that may have occurred while you were truing the spring in the round.

HAIRSPRING VIBRATING

When you repair a watch or clock, you must know how to select the RIGHT hairspring for a given balance wheel. The spring must be of such length and strength that it will cause the balance wheel to vibrate a certain number of times per hour. The process for selecting a

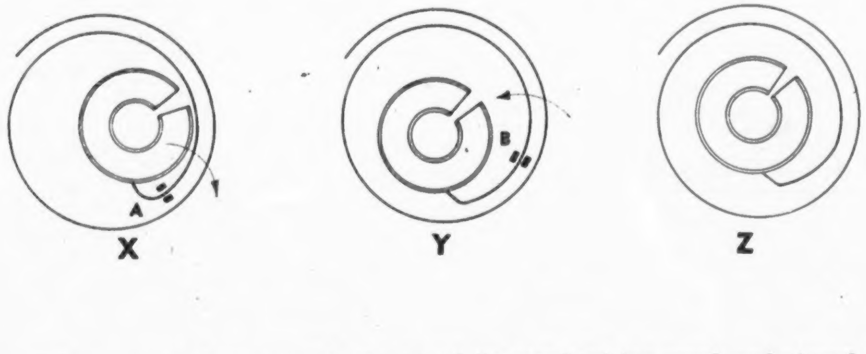


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Figure 6-61.—Correction of an error in the round (tongue bent too much and pinned in too far).

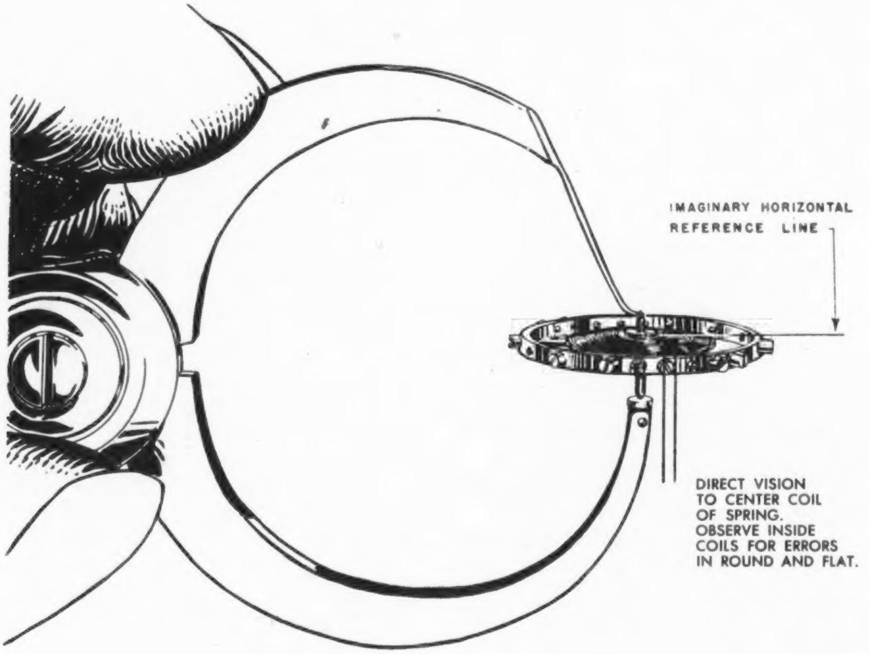
IMAGINARY HORIZONTAL REFERENCE LINE
DIRECT VISION TO CENTER COIL OF SPRING. OBSERVE INSIDE COILS FOR ERRORS IN ROUND AND FLAT.

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Figure 6-62.—Checking a hairspring for errors in the round and in the flat.

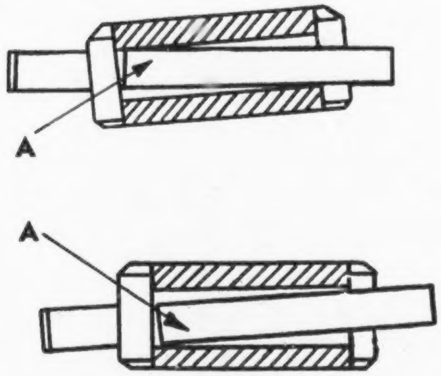

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Figure 6-63.—Hairspring errors in the flat.

hairspring with such characteristics is called HAIRSPRING VIBRATING. The vibrating point of a hairspring IS THE POINT WHICH IS LOCATED between the regulator pins of a watch.

Before we consider the details of hairspring vibrating, it is best that we first define two words, VIBRATION and OSCILLATION. If the prongs of a tuning fork are struck on a desk and then held free, they vibrate and oscillate. When a prong of the tuning fork swings in one direction as far as the fork frame permits it to go, it VIBRATES; when the same prong returns to its starting position, it VIBRATES A SECOND TIME. A vibration, therefore, is a SINGLE SWING from one extreme limit to the other extreme limit of an oscillating body; an oscillation consists of TWO VIBRATIONS.

The property of a metal rod or body which causes it to vibrate is ELASTICITY. If the free end of an elastic rod (prong of tuning fork, for example) is set in motion by external force, it continues to vibrate at a constant rate until all the energy stored up in it by the force which set it in motion is expended. This quality of elasticity of a metal rod led to the development of the hairspring, so called because of its delicate nature.

The idea was conceived by watchmakers that if a fine steel rod were formed into a spiral and its outer end attached to the pillar plate of a watch and its inner end connected to the balance wheel, when set in motion, the balance wheel would vibrate a number of times per second. They learned that the number of vibrations per second was dependent upon the LENGTH and STRENGTH of the spring and the WEIGHT of the balance wheel. These three factors must therefore BE CONSIDERED when you select a hairspring for a particular balance wheel.

Now study figure 6-64, which shows a portion of a hairspring. Note all dimensions, particularly THICKNESS, which is referred to as the STRENGTH of a hairspring. The strength of hairsprings is generally indicated by a number on the box in which the manufacturer ships them. In the Swiss system, these numbers range from 18 to 96—the lower the number, the THICKER and STRONGER the spring.

All stock hairsprings of a GIVEN NUMBER, however, do NOT HAVE the same strength and, for this reason, you must use ANOTHER METHOD for determining which hairspring to use for a specific balance wheel. The method for making this determination is known as HAIRSPRING VIBRATING.

Before you vibrate a hairspring, make a preliminary check TO DETERMINE ITS SUITABILITY for the watch in which you intend to use it. This check may save you TIME and LABOR.

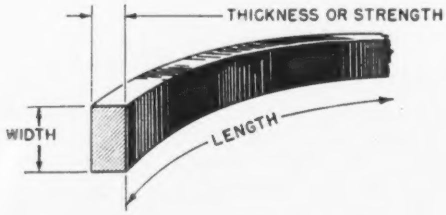

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Figure 6-64.—Dimensions of a hairspring.

Preliminary Check of a Hairspring

Suppose you need a hairspring for an average watch whose balance vibrates 18,000 times per hour (300 times per minute) and you have available hairsprings whose numbers indicate they are close to what you need. How can you make a preliminary check to determine their suitability (individually) for the balance wheel in question? Proceed as follows:

1. Attach the new spring to a balance wheel.
2. With a pair of tweezers, grasp the spring a short distance from its outer end and let the balance assembly hand by its own weight, as illustrated in figure 6-65.
3. Count the spaces between the coils, downward from the point of suspension. If your count is 8 or 9, and if there are NO LESS THAN 12, and NO MORE THAN 14 whole coils between your tweezers and the pinning-in hole in the collet, the spring IS SUITABLE for the balance wheel.

The spot at which you FIRST GRASP the hairspring may not give you the correct count of whole coils between your tweezers and the pinning-in hole in the collet. When this is true, experiment with different spots until you locate the CORRECT SPOT on the hairspring which gives you the desired count. You will then find that the diameter of the spring is approximately EQUAL TO THE RADIUS OF THE BALANCE

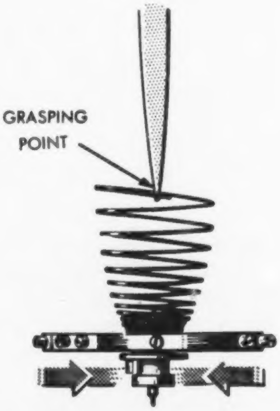

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Figure 6-65.—Preliminary check of a hairspring.

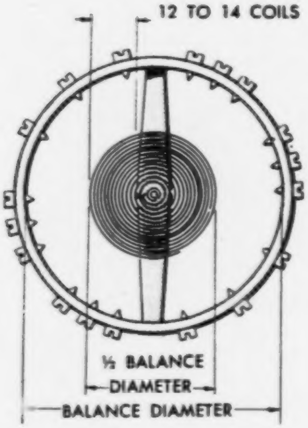

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Figure 6-66.—Diameter of a correct hairspring equals the radius of the balance wheel.

WHEEL (fig. 6-66). Observe that the hairspring illustrated has 12 to 14 coils.

Methods of Vibrating

Two different methods are generally used for vibrating hairsprings, OSCILLATION COUNTING and MASTER BALANCE. Each method is discussed in sufficient detail to enable you to understand how to use it.

OSCILLATION COUNTING METHOD.—The procedure for selecting a hairspring for an average watch whose balance wheel oscillates 150 times per minute, using the oscillation counting method, is outlined in the following paragraphs:

1. Pick up the hairspring with tweezers at the point you located during the preliminary test, and then lower the balance assembly until the lower balance pivot touches the crystal of a watch with a second hand, as illustrated in figure 6-67.
2. Grasp the balance wheel with the right hand and turn it counterclockwise to put the tension in the hairspring.
3. Suddenly release the balance wheel to allow the hairspring to put it into vibration. Observe the extreme position of the balance arm of the wheel and then note the position of the second hand of the watch.
4. Begin with zero and count every OTHER vibration of the balance wheel.

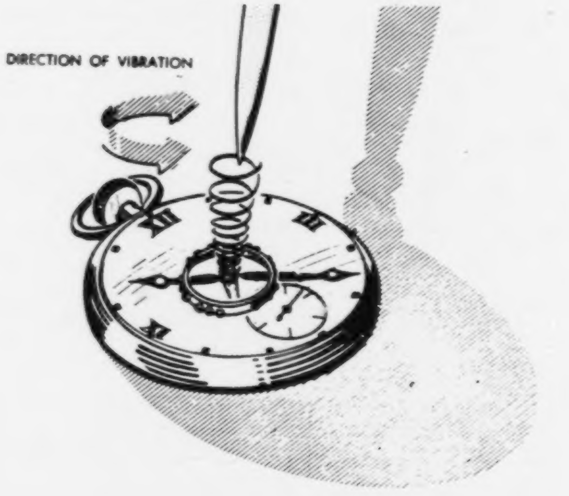

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Figure 6-67.—Oscillation counting method of hairspring vibrating.

For a vibrating hairspring whose count is to be 18,000 vibrations per hour, the agreement (coincidence) of count with the second hand is as follows: (Use every other vibration as a count of one. Two vibrations equal one oscilation.)

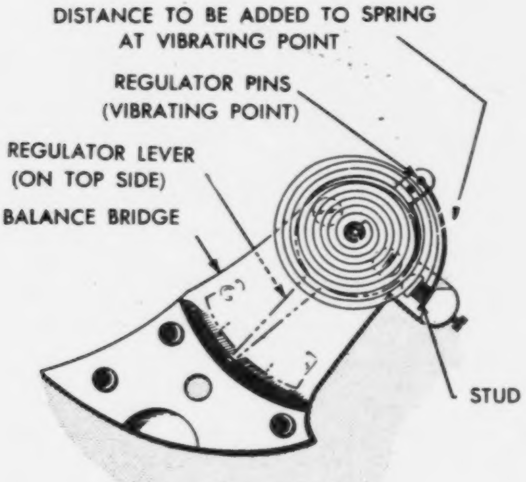
2.5 counts	1 second
5 counts	2 seconds
10 counts	4 seconds
25 counts	10 seconds
75 counts	30 seconds
175 counts	60 seconds

If your count shows 25 for each 10 seconds, the balance wheel and hairspring undergoing the test are vibrating 18,000 per hour, the correct number of times desired. For the sake of accuracy, however, always make your count over ONE FULL MINUTE. If the count is greater than 150 for a minute, or more than 25 for 10 seconds, the length of the hairspring is TOO SHORT. If the count is less than 150 for a full minute, or less than 25 for 10 seconds, the hairspring is TOO LONG.

The point at which you grasped the hairspring with tweezers for making your CORRECT COUNT should be located between the regulator pins of the watch. In other words, the active length of a hairspring terminates at the regulator pins, which is the POINT OF VIBRATION. Study figure 6-68. The actual length of the hairspring ends at the stud. Enough spring must therefore extend beyond the vibrating point to allow for studding (fig. 6-68).

When you stud a hairspring, center the regulator on the balance bridge (fig. 6-68) and hold the spring with the tweezers at the regulator pins (vibration point). Then make a measurement on the outer coil of the spring from the vibration point toward the end of the spring, equal to the distance from the regulator pins to the stud, plus enough spring to go through the stud (fig. 6-68). Allow just a bit of the outer coil to extend through the stud and break it off at this point.

MASTER BALANCE METHOD.—The way to find the vibrating point of a hairspring by the master balance method is to compare the rate of oscillation of the balance wheel and hairspring with that of a master balance, shown in figure 6-69.


DISTANCE TO BE ADDED TO SPRING AT VIBRATING POINT
REGULATOR PINS (VIBRATING POINT)
REGULATOR LEVER (ON TOP SIDE)
BALANCE BRIDGE
STUD

91.223X
Figure 6-68.—Vibrating point of a hairspring.

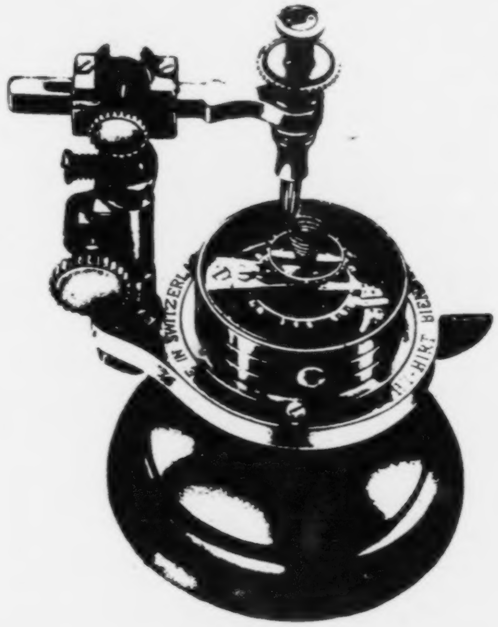


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Figure 6-69.—Vibration counting with a master balance.

A master balance is a tool with a master balance wheel and hairspring enclosed in a glass covered case for protection. The balance wheel is accurately adjusted to vibrate 18,000 times per hour. It has a pair of tweezers secured to the end of an adjustable horizontal arm that extends over the face of the balance for holding a balance wheel undergoing a test. By means of adjustment screws, you can move the tweezers up and down, or out or in from the upright rod which holds the horizontal arm. The tweezers have a plunger for opening and closing the jaws. The balance also has a starting lever for starting the balance wheels in motion, and a stop button for stopping them from vibrating.

The procedure for locating the vibrating point of a hairspring with a master balance follows:

1. Place the outer coil of the hairspring between the tweezer jaws, as illustrated in figure 6-69.
2. Unscrew the lower adjustment knob and lower the tweezers enough to bring the lower pivot of the test balance wheel into contact with

the glass cover above the master balance wheel. Contact with the glass cover over the master balance steadies the test balance while it vibrates and makes observation easier.

3. Adjust the arms of the test balance wheel by turning the master balance tweezers in their friction support.

4. Start the master balance by depressing and releasing the starting lever, which gives the starting impulse to the master and test balance wheels simultaneously.

5. Watch the arms of both balance wheels as they vibrate. If they are in exact synchronization with each other, the tweezers are holding the test hairspring at the EXACT POINT OF VIBRATION. If one balance wheel begins to move out ahead of the other, THAT WHEEL IS THE FASTER.

6. If the test balance wheel steps out of synchronization first, the active length of its spring is TOO SHORT. Depress the stop button of the master balance and reset the tweezers so as to increase the active length of the test hairspring. Re-start the master balance and observe the arms of the two balance wheels. Continue increasing or decreasing the active length of the test hairspring until you have the balance wheels in perfect synchronization.

After you find the vibrating point of a hairspring, you can then proceed with the studding operation, described under the OSCILLATION COUNTING method of hairspring vibrating.

OVERCOILING

Overcoiling is the process of forming the outer coil of a hairspring in a manner that will ensure the following conditions when the hairspring is operating in a watch:

1. The center of gravity of the spring consistently COINCIDES with the axis of the balance staff.

2. As the spring winds and unwinds, its coils remain concentric with the axis of the balance staff, and its elastic force increases and decreases in proportion to the angle of rotation of the balance wheel from the line of centers.

3. The spring DOES NOT CAUSE the balance pivots at any point in their angular movement to exert a side thrust or pressure against their jeweled bearings.

4. The balance unit makes each swing (vibration) in the SAME AMOUNT OF TIME regardless of the size of the arc and impulse causes it to make while travelling.

A balance unit which operates in the manner just described is called an ISOCHONAL BALANCE UNIT; that is, the torque on the balance staff is always directly proportional to the angle through which the balance turns.

A flat hairspring has a characteristic that causes its coils to bunch together first on one side of the balance staff and then on the other as it vibrates. Because of this action, a side thrust (pressure) is created between the balance pivots and their jeweled bearings.

As a flat hairspring is wound, the pressure (side thrust) is exerted in a direction AWAY from the regulator pins. See part A of figure 6-70. As the spring unwinds, the side thrust is exerted TOWARD the regulator pins (part B, fig. 6-70). This pressure causes an unequal turning action (torque) on the balance staff—the greater the swing of the balance, the greater the side thrust and resulting friction.

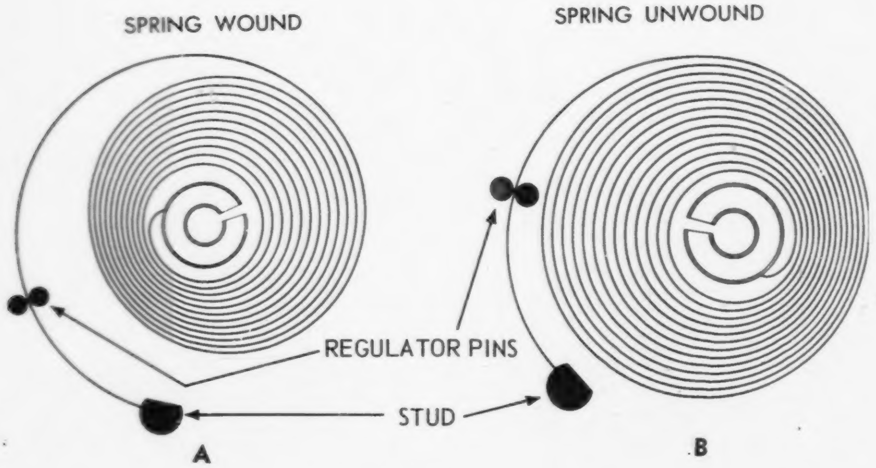
This torque means that energy received by the roller jewel from the pallet does not ALL GO into winding and unwinding the hairspring—some of it is dissipated in overcoming friction. Because of this, the force exerted on the balance staff by the hairspring is NOT DIRECTLY PROPORTIONAL to an angle through which the balance staff turns. A watch with such a hairspring GAINS in the high arcs and LOSES in the low arcs of motion. In other words, it is NOT an isochronal hairspring.

In order to overcome the lack of uniformity in rate of a flat hairspring, watchmakers knew they would have to alter the shape of the hairspring in a manner that would ensure uniformity of rate in HIGH and LOW arcs of motion. As a result of their ideas and experiments, a new type of hairspring was developed.

Breguet (Overcoil) Hairspring

A Swiss horologist, Louis Breguet, conceived the idea that if the outer coil of a flat hairspring were bent up and laid over the top of the main body of the spring the spring would wind and unwind concentrically—it would be free of side thrust, and the force on the balance would be proportional to the angle through which it turned.

At first, Brequet made two bends (up to get the rise, then down to get the coil in a horizontal plane) in the outer coil of a hairspring opposite the mouth of the collet and brought the coil straight across the hairspring to the stud.



91.225X

Figure 6-70.—Characteristics of wound and unwound flat hairsprings.

This type of overcoil, however, produced an error opposite the one produced by a flat hairspring—a faster rate in the low arcs of motion than in the high arc. Breguet therefore decided that between the two extremes there must be a place to lay the overcoil which would cause the balance wheel to make its vibration in the same time, regardless of whether it swung in a high or low arc of motion. Because he DID FIND the correct place to lay the overcoil on a hairspring to give it isochronal qualities, the overcoil hairspring is frequently called the BREGUET HAIRSPRING.

Three basic types of overcoils in hairsprings are in common use today. See figure 6-71. When you select one of these overcoils for use on a hairspring, take into consideration the location of THAT PORTION of the overcoil represented by AB in figure 6-71 in relation to the balance staff. If line AB is located too close to the balance staff, the watch will GAIN in the low arcs and lose in the high arcs of motion. If AB is located TOO FAR FROM the balance staff, the watch will have a losing rate in the low arcs and a gaining rate in the high arcs.

Overcoiling Procedure

In making an overcoil on a hairspring, avoid weakening or damaging the spring by A SHARP BEND. It is best for you to practice making bends on an old hairspring until you learn the technique for making them correctly.

Two types of tweezers are used in making overcoils, as shown in figure 6-72. Regular overcoiling tweezers have ends made in various widths for different sizes of springs. The inside of one leg is convex; the opposite leg is concave, which means that when closed the legs fit closely together. Knee-bend overcoiling tweezers are good for making a variety of adjustments on springs of different sizes. Study the enlarged portion of the tweezer points in figure 6-72. To prepare these tweezers for use, make two adjustments: (1) adjust the width of the slot in the tweezers by the slide and small setscrew A; and (2) regulate the distance apart the tweezer points should be when closed by setscrew B. The last adjustment determines the angle of rise of the overcoil from the main body of the spring. With practice in making bends on a discarded hairspring, you will soon learn how to adjust and use overcoiling tweezers.

Suppose you need to put an overcoil on a hairspring like the one illustrated by B in figure 6-71. What procedure would you follow to make this overcoil? The discussion in the next paragraphs explains the procedure.

THE FIRST BEND.—Start the first bend of the overcoil at point A, about 270° from the stud

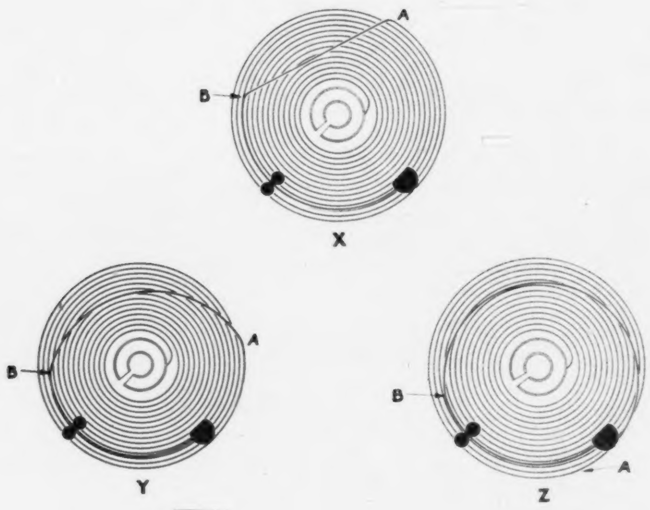


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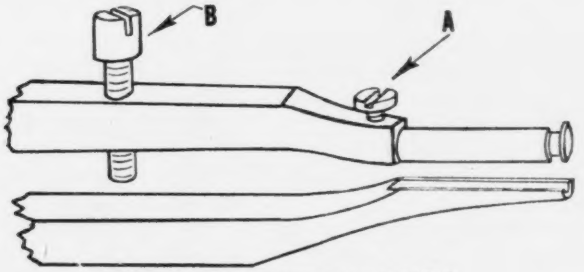
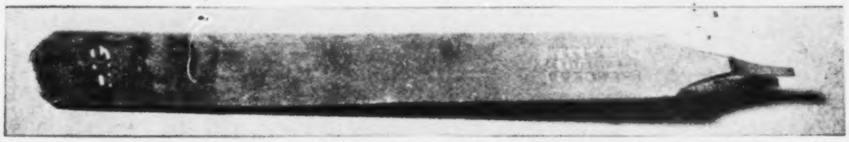
Figure 6-71.—Three basic types of hairsprings overcoils.



ENLARGED VIEW OF DISASSEMBLED TWEEZERS

KNEE BEND OVERCOILING TWEEZERS



REGULAR OVERCOILING TWEEZERS

61.77X

Figure 6-72.—Overcoiling tweezers.

(part X, fig. 6-73). NOTE: This angular measurement varies with different sizes and types of balance units. Suspend the spring with a pair of ordinary tweezers and allow the balance wheel to hang by its own weight, as shown at T (about 45° to the right of A) in part Y of figure 6-73. Then insert the hairspring in the slotted end of the knee-bend tweezers (concave part below slotted part) and apply pressure to put as much bend in the coil as setscrew B in the tweezers allows. When you remove the tweezers from the coil, your bend should look like the one illustrated by A in part Z of figure 6-73. This is about a 25° rise from the main body of the spring.

THE SECOND BEND.—The second bend in the coil is located at B (parts X, Y, and Z of fig. 6-74). The purpose of this bend is to bring the overcoil into a plane parallel with the main body of the spring. The location of point B is determined by the height desired for the overcoil above the spring. This bend is usually 2 1/2 times the width of the spring (part Z,

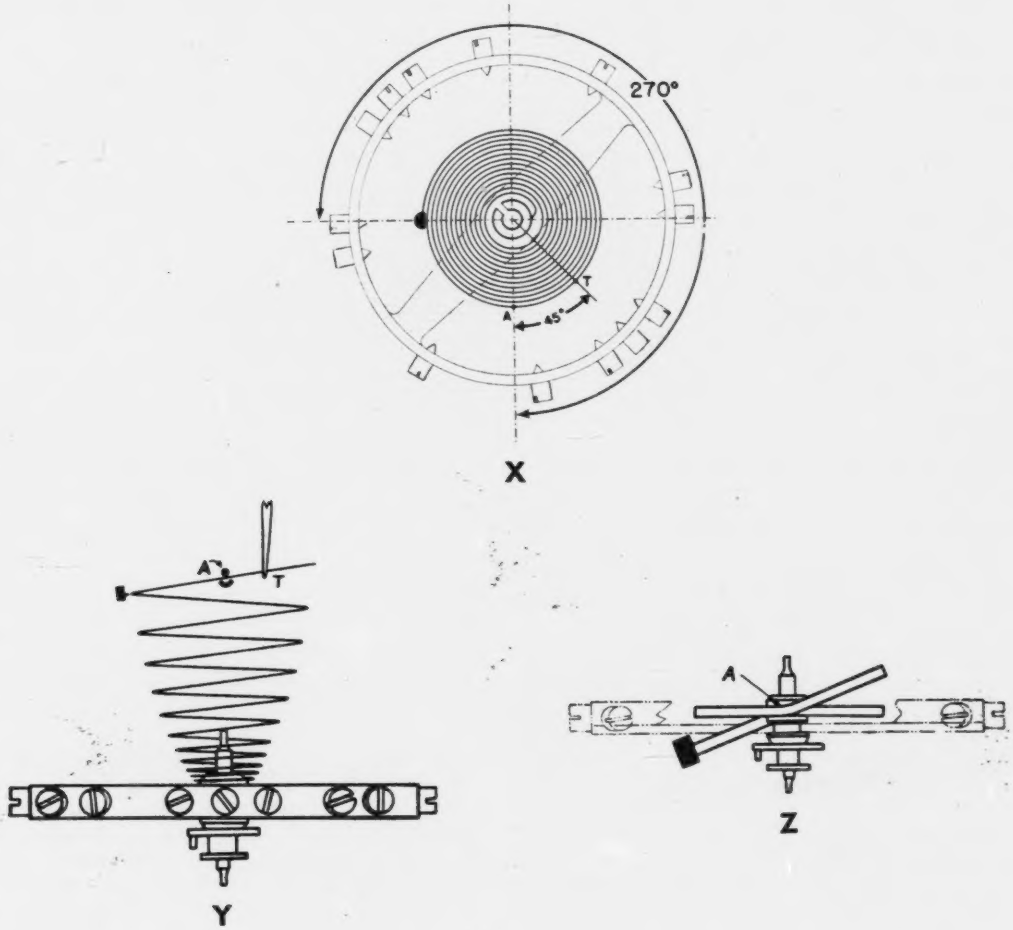


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Figure 6-73.—Making the first bend of an overcoil.

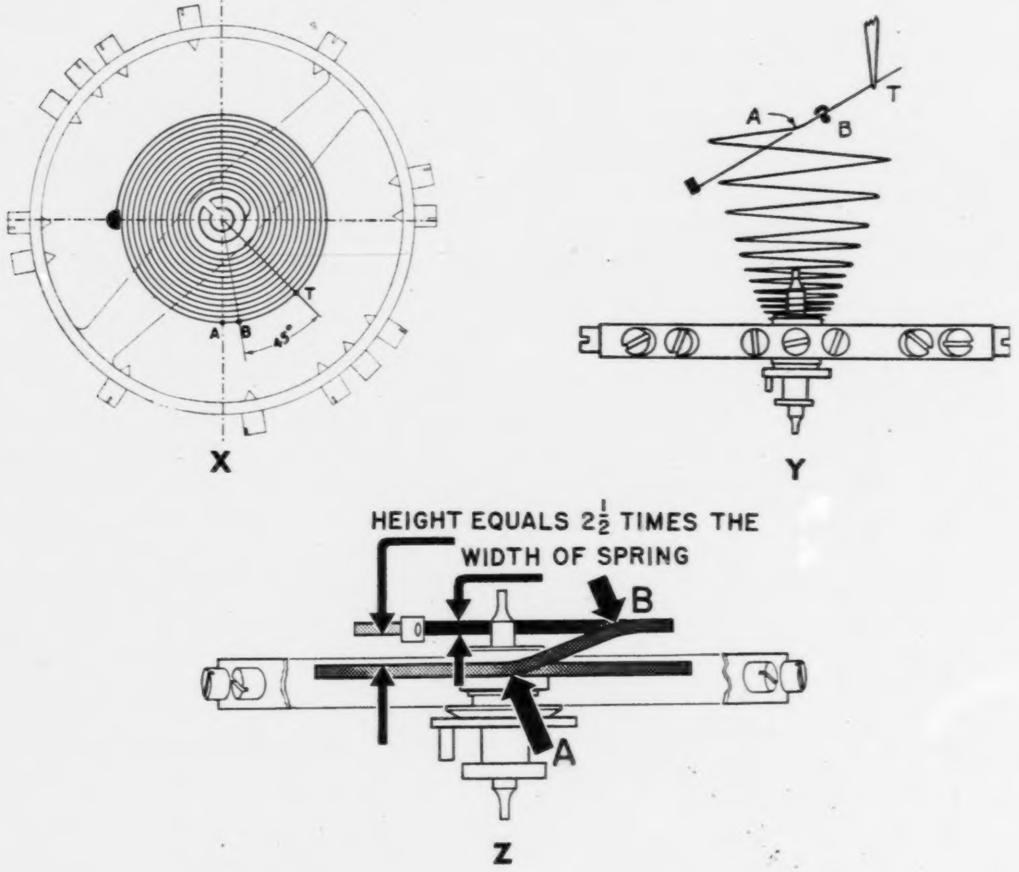

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Figure 6-74. — Forming the second bend of an overcoil.

fig. 6-74). To make the bend, use two steps: (1) grasp the coil with ordinary tweezers at T, about 45° from point B; and (2) apply the knee-bend tweezers at B (concave part above slotted part) and press them together as much as possible. When the bend is completed, the hairspring will have the appearance of the one shown in part Z of figure 6-74.

After you make the bend of the overcoil at B, you will find that the overcoil is not exactly parallel with the main body of the spring—a point 180° from B is TOO LOW. To make the overcoil parallel with the rest of the spring, grasp it a little to the left of bend B with a pair of ordinary tweezers held upright in the left hand and bend the overcoil toward you with another pair of tweezers placed upright on the overcoil slightly to the right of B.

THE THIRD BEND. — Make the third bend in the overcoil at point C (fig. 6-75). Use a pair of regular overcoiling tweezers to effect this bend, about 45° from bend A. Execute the bend by grasping the overcoil at point C with the convex leg of the tweezers nearest the balance staff and by squeezing the tweezers until you have the overcoil at point D nearly halfway between the outer coil and the collet.

THE FOURTH BEND. — The fourth bend of the overcoil goes at point E (fig. 6-75). To get the correct position for this bend, measure

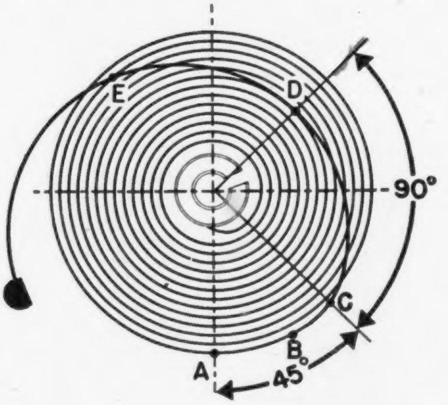

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Figure 6-75.—The third bend of an overcoil.

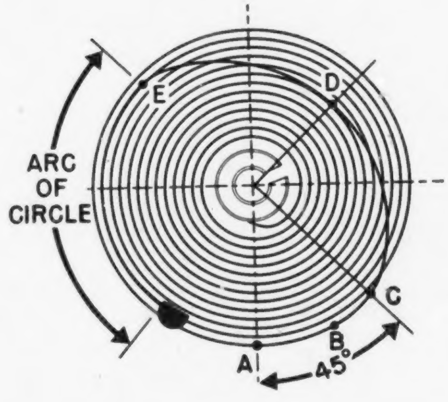

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Figure 6-76.—Making the fourth bend of an overcoil.

the distance from the hole jewel in the balance bridge to the regulator pins. This bend is the regulator circle (arc) in the outer coil, and it is the final step in overcoiling. The regular pins are mechanically held at a fixed distance from the hole jewel and move in an arc of a circle. For this reason, the part of the overcoil that lies in the path of the regulator pins must be a perfect arc of a circle and be free of small kinks; otherwise, proper regulation of the watch will be impossible.

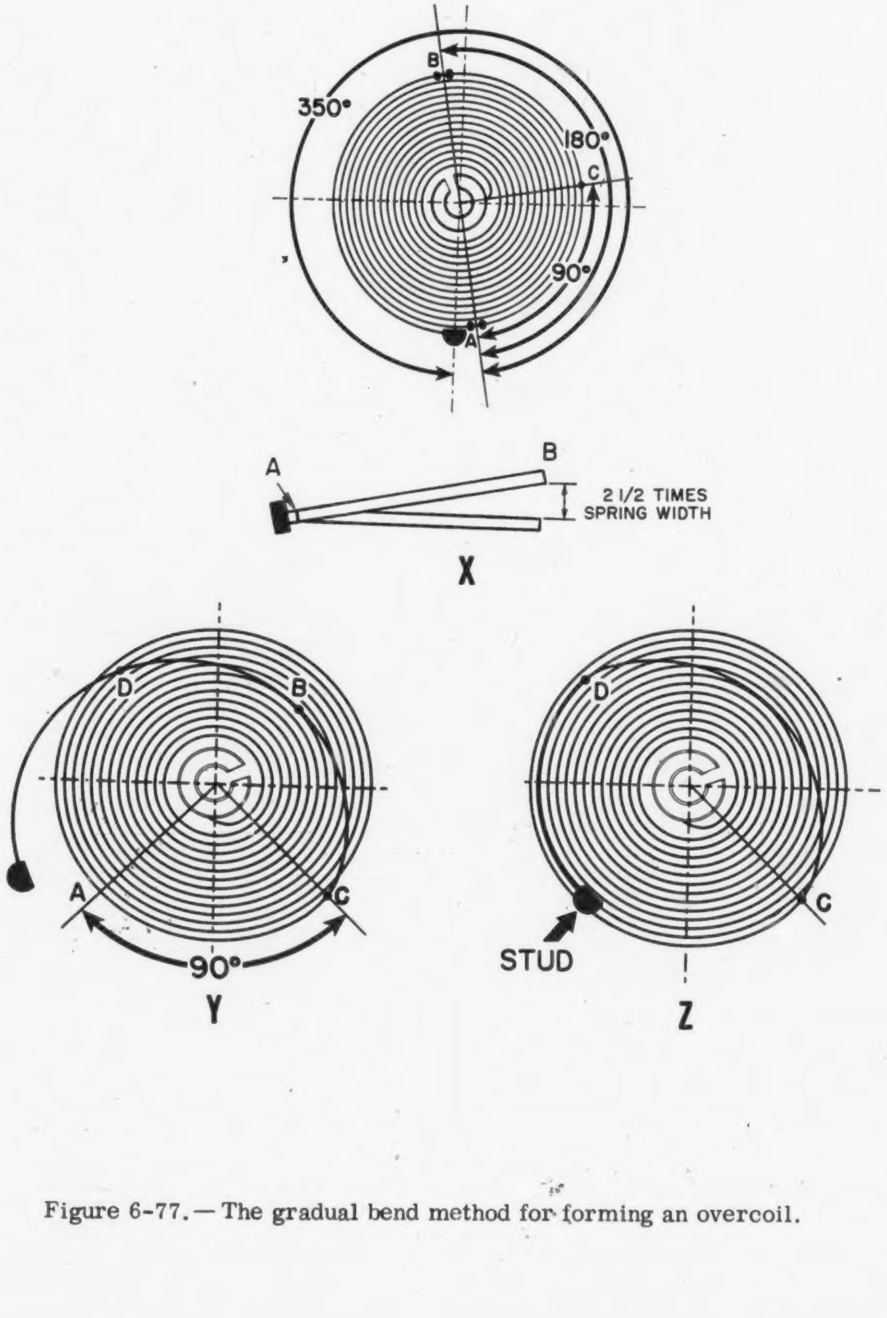
You can form the regulator circle in the outer coil of a hairspring in two ways: (1) grasp the overcoil with tweezers (perpendicular to the spring) at E and, through proper application of pressure, form an arc which looks like the one from E to the stud in figure 6-76; and (2) grasp and push on the outside of the coil with another pair of tweezers until you form an arc between E and the point where you applied the pressure. CAUTION: If you apply pressure TOO CLOSE to point E, you will make a kink in the coil. Continue in this manner to form a second portion of the regulator circle, and then continue as necessary until you finish the arc.

Gradual Bend Method of Overcoiling

Another method for bending the outer coil of a hairspring in order to form an overcoil is used to such an extent that it warrants explanation. It is known as the GRADUAL BEND METHOD. The procedure for forming an overcoil by this method follows.

First, make the initial bend at A (part X, fig. 6-77), about 350° from the stud. NOTE: This measurement varies in accordance with requirements for different balance units. Grasp the unstaked hairspring at A with a pair of ordinary tweezers held vertically against the bench surface with the left hand. With another pair of tweezers, held vertically in the right hand, grasp the coil about one millimeter to the right of the other tweezers. Hold the tweezers in the left hand still and tilt the tweezers in the right hand toward your body. This movement bends the spring in such manner that point B, 180° away, is the highest point. Then put another bend in the spring at A in order to raise point B UP 2 1/2 times the width of the spring.

Next, turn the spring clockwise until point B is near you, and grasp it at this point with a pair of tweezers held in the right hand and against the bench surface. About one millimeter to the left, grasp the spring with the other pair of tweezers held in the left hand. NOTE: Keep inner surfaces of the tweezers in the same plane as that of the portion of the hairspring to be bent. Hold the left hand steady and tilt the tweezers in the right hand until the top comes toward you. This manipulation bends the part of the overcoil between B and the stud upward. Put enough bend in the overcoil at B to bring it into a plane parallel to the main body of the spring.


B
350°
180°
C
90°
A
A
B
2 1/2 TIMES SPRING WIDTH
X
D
B
A
C
90°
Y
D
C
STUD
Z

91.231X

Figure 6-77. — The gradual bend method for forming an overcoil.

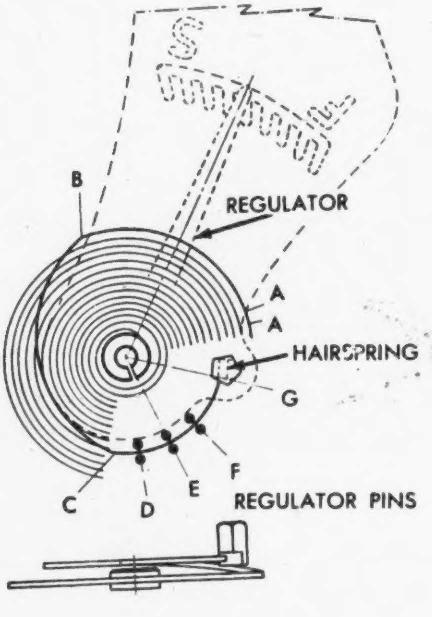
With regular overcoiling tweezers, make the FIRST INWARD BEND at point C, 90° from point A. Exert enough pressure on the tweezers to move point B almost halfway between the collet and the outer coil (part Y, fig. 6-77). Using the same tweezers, make the next bend at D, where the overcoil crosses over the second coil.

Use either of the overcoiling methods just described to form the regulator circle from point D to the stud. Make a knee-bend overcoil. Part Z of figure 6-77 shows how the completed overcoil and spring look.

Finishing Procedure

When you form an overcoil on a hairspring in the correct manner (parallel with the main body of the spring, properly circled, centered), and with the regulator pins correctly located, no finishing touches are required. The only remaining thing to do is to put the balance unit in the watch.

If an overcoil does not have the characteristics listed in the previous paragraph, one of the following conditions is probably causing the imperfection:



91.232X

Figure 6-78.—Overcoil circled between regulator pins.

1. The height of the overcoil above the main body of the spring is INCORRECT.
2. The overcoil is NOT PARALLEL to the hairspring body.
3. The distance of points, C, D, E, F, and G from the balance staff ARE NOT UNIFORM (fig. 6-78)
4. The hairspring stud IS NOT PLACED at a proper angle to the hairspring.
5. The hairspring IS BENT at the entrance to the stud (G in fig. 6-78).
6. The distance from the balance staff to the center line of the regulator pins IS NOT UNIFORM.

You can correct the first three conditions by bending and reforming the overcoil. Center the stud on a line passing through it and the center of the collet.

If you bent the overcoil TOO FAR TOWARD the balance staff when you secured it to the stud, it will strike against the inner regulator pin and throw the remainder of the overcoil out of position. Move the regulator to the SLOW side of the balance cock (point F). Then move from SLOW to FAST (from F to D). If the overcoil moves AWAY from the balance staff as you move the regulator pins from F to D, the end section of the overcoil is not properly circled and must be corrected, as follows:

1. Move the regulator pins as close as possible to the stud and bend the overcoil OUT and AWAY from the balance.
2. Move the regulator pins from SLOW to FAST and observe the action of the overcoil. If it remains MOTIONLESS, your bend in the overcoil was sufficient to make proper correction.

If when securing the overcoil to the stud you bend it TOO FAR AWAY from the balance staff, it will strike against the outer regulator pin and throw the rest of the coil TOO FAR OUT from the balance staff. Move the regulator pins from SLOW TO FAST and observe the action of the overcoil. If it moves TOWARD the balance staff, make necessary corrections (with regulator pins straight) by bending the overcoil TOWARD the balance staff. With a strong loupe, check this part of the overcoil by moving the regulator pins slowly to their different positions, with the balance wheel stopped and the roller jewel in the fork slot.

CHAPTER 7

WATCH AND CLOCK ADJUSTMENTS

Watches and clocks used aboard ship and throughout the Navy must be reliable and accurate; and when maintained in excellent operating condition, they generally have these attributes. As an Instrumentman, it is your responsibility to overhaul and repair watches and clocks, including proper adjusting and regulating.

Before you can qualify for advancement to a Chief Instrumentman, you must know such things about watches and clocks as common causes of motion variation between dial-up and 12-up positions, operation of a watch rate recorder and interpretation of data obtained thereby, and the accepted techniques of testing for and correcting positional and isochronal errors.

Watch and clock adjusting may be defined as the ELIMINATION OF CONDITIONS in a watch or clock which affect the degree of accuracy of which the timepiece is capable. Watch adjusting is normally limited by definition to the correction of errors or faults in the hairspring and balance wheel which interfere with accurate timekeeping. This definition, in essence, is true; because the balance assembly is the timekeeping mechanism. The mainspring, the main train, and the escapement serve only to keep the balance in motion. When these parts of a timepiece are functioning perfectly, adjusting does consist of the correction of conditions which adversely affect satisfactory operation of the balance assembly.

Adjustments made on watches and clocks to improve their accuracy are generally classified under three headings:

1. Temperature adjusting (compensations for).
2. Isochronal adjusting (elimination of isochronal errors).
3. Position adjusting (adjustments with PENDANT UP, PENDANT DOWN, DIAL UP, and so forth).

These three types of adjustments are discussed in detail in this chapter. At this time, however, it is best to take into consideration the operation of a watch and clock timing machine, and to explain how data obtained by testing a watch or clock on this machine can be used in making adjustments to the timepiece.

TIMING MACHINE

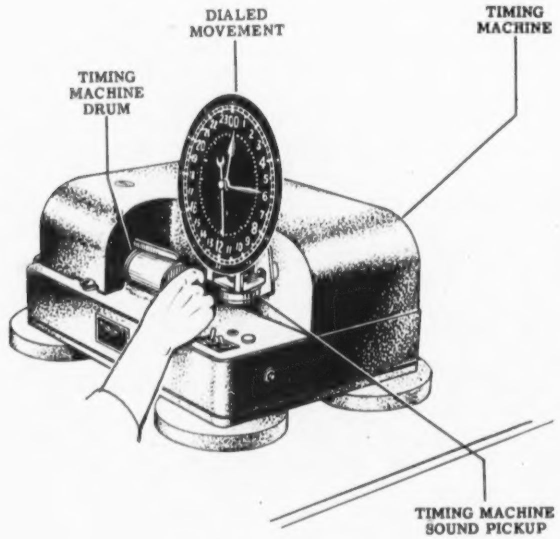
A timing machine is a mechanism which records the operation of a mechanical timepiece on a strip of special chart paper. One type of timing machine is illustrated in figure 7-1.

A timing machine makes a dot on the chart every time the timepiece undergoing a test TICKS, and it can determine in 30 seconds how FAST or SLOW it will run in 24 hours. The completed chart consists of a sequence of these dots across the chart.

TYPES OF TIMING MACHINES

There are two basic types of timing machines: (1) drum, and (2) continuous-tape. The one shown in figure 7-1 is a drum type, which makes a line of dots from left to right on a chart. Beneath the clamp which holds the clock on the machine is a sensitive pickup which detects the impulse from the escapement. When amplified by the timing machine, this impulse drives a stylus which prints the impulse on the chart. A perfectly adjusted escapement produces only one line on the paper, but some clock movements may produce records with double lines and still keep accurate time.

A continuous-tape timing machine makes a row of dots on a tape which unwinds from top to bottom. A vertical row of dots indicates NEITHER a GAIN nor a LOSS of time. If the row of dots slopes to the left, the timepiece is running SLOW; if the row of dots slopes to the right, the timepiece is running FAST.



91.255
Figure 7-1. — Timing machine.

TIMING MACHINE DATA

A timing machine chart record of ticks may be used to tell exactly how fast or how slow a watch is running; and the chart record may also be used by an experienced watch repairman to diagnose certain troubles in the instrument being tested.

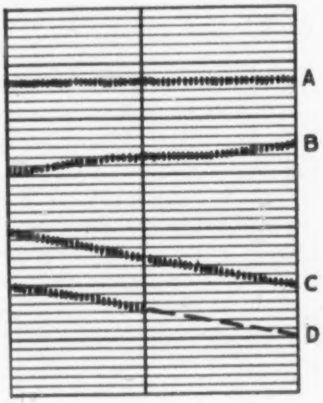
By studying a chart produced on a continuous-tape timing machine, you can tell whether the timepiece undergoing a test is losing or gaining time by the angle of the row of dots away from the vertical line, which indicates perfect timekeeping. The angle indicates the number of seconds per day the timepiece is GAINING or LOSING. A convenient angle-measuring device graduated in seconds per day is mounted over the tape.

A horizontal line of dots on a chart produced by a drum-type timing machine indicates that a timepiece being tested is NEITHER LOSING nor GAINING time. When the row of dots rises upward (left to right), the instrument is gaining time. When the row of dots fall downward (left to right), the timepiece is LOSING time. The chart paper is marked with ruled lines which show the GAIN or LOSS per day in seconds, indicated by the rise or fall of the dots from the horizontal line.

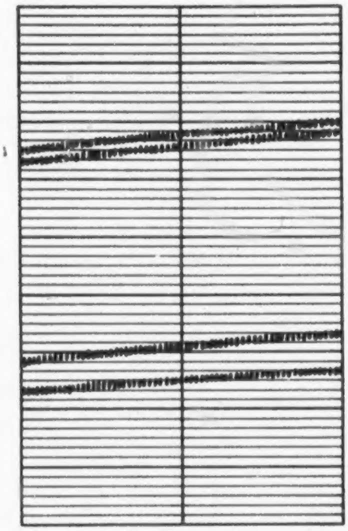
Take a look now at figure 7-2, which shows four different records of a watch taken on a drum-type timing machine. Record A represents the watch EXACTLY on time. Record B shows that the watch is gaining 15 seconds per day. Record C represents the watch losing 30 seconds per day. Record D (prepared in 15 seconds) represents the watch losing 30 seconds per day.

Illustration 7-3 shows two different records of a timepiece. The double lines on this chart represent the difference in time between the TICK and TOCK, and the TOCK and TICK. When a timepiece is in perfect beat, this separation (two lines of dots) may be caused by excessive SLIDE of the escapement. In general, however, if the two lines are parallel, the timepiece is accurate.

Many watches have unpoised balance and hairspring assemblies, resulting in differences in rate in various vertical positions. Study figure 7-4. Records A, C, and E show a watch in acceptable condition. Records B and D show that the watch is out of balance in these particular positions. If the watch is not affected in positions A, C, and E (and the recordings of B and D are such that these two positions do not exceed accepted limits for this type of watch), the watch is acceptable.



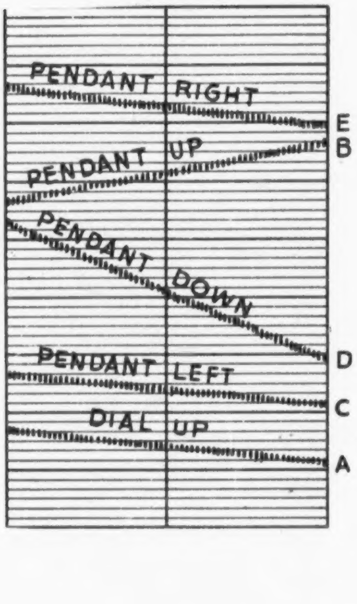
91.256
Figure 7-2.—Timing machine records of a watch.



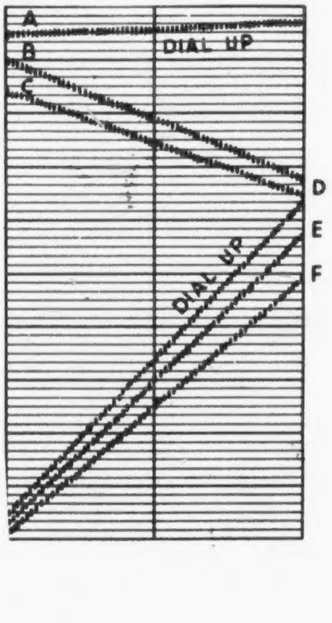
91.257
Figure 7-3.—Two records of a watch which is gaining 15 seconds per day.

Records A, B, and C of figure 7-5 show three positions of a watch in which the regulator pins may be excessively far apart. The horizontal rate is approximately correct, but the PENDANT DOWN (B) and PENDANT UP (C) rates are slow. Records D, E, and F show the rate of the watch in the same three positions after the regulator pins were closed sufficiently to obtain proper action of the hairspring between them. Moving of the regulator pins in this manner has the effect of making the watch run faster in all positions, but the change in the vertical position rates is greater than the change in the horizontal position rates. This action brought the position error into ACCEPTABLE LIMITS. Records D, E, and F show that the watch is gaining 3 minutes every 24 hours in the horizontal position, but correction can now be made by adding balance weights, rather than by manipulating the regulator pins.

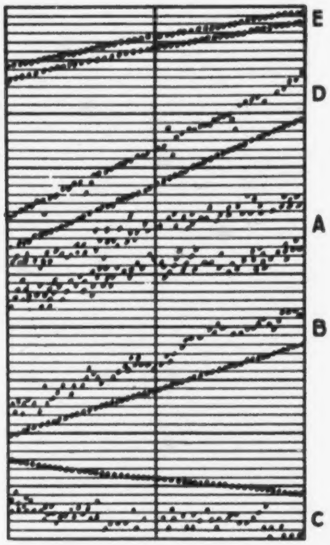
The hairspring is responsible for much of the ordinary trouble in a timepiece, particularly with respect to its relation with the regulator pins, and also in regard to defects in the escapement. Refer to figure 7-6. Record A of this illustration may indicate that the hairspring bears harder and



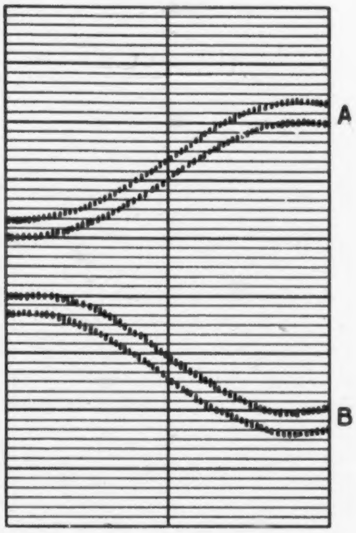
91.258
Figure 7-4.—Record of a watch with an out-of-poise balance.



91.259
Figure 7-5.—Record of a watch with improperly adjusted regulator pins.



91.260
Figure 7-6. — Record of a watch which has poor adjustment of the hairspring and regulator pins.

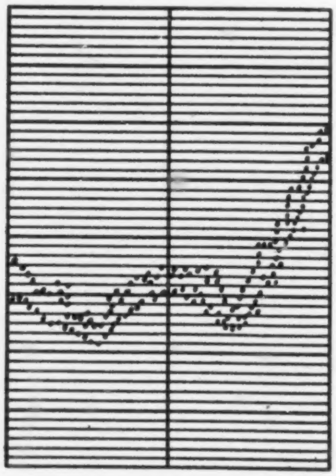


91.261
Figure 7-7. — Rate records of a watch with defective fourth wheel or a binding second hand.

longer against one of the pins. Record B may show that one of the pins is bent at an angle, or that trouble exists in the receiving stone of the pallet. Records B and C may indicate improper locking of the escapement. Record C may indicate trouble in the discharge stone of the pallet. Record D shows good adjustment of the hairspring and escapement, but it may indicate that the movement would perform better if it were in beat. The lines on the chart would then be closer together, as indicated by record E.

The chart in figure 7-7 shows trouble in a watch caused by a defective fourth wheel or a second hand binding or rubbing on one side. If the fourth wheel (normally makes one complete revolution per minute) is out of round, or has a bent pivot or arbor, it causes a change in the amount of power delivered to the escape wheel and the balance assembly. This causes a change in the rate of the watch, as does the rubbing or binding of a second hand.

Next, study the record shown on the chart in figure 7-8, which shows that dirt or a binding in the main train or of the mainspring in the barrel is causing a change in the power delivered to the balance assembly.

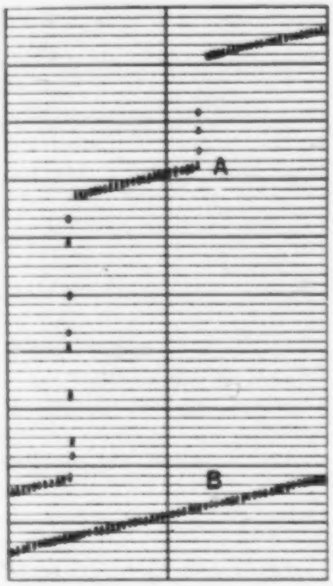


91.262
Figure 7-8. — Record of a watch which has binding parts or is dirty.

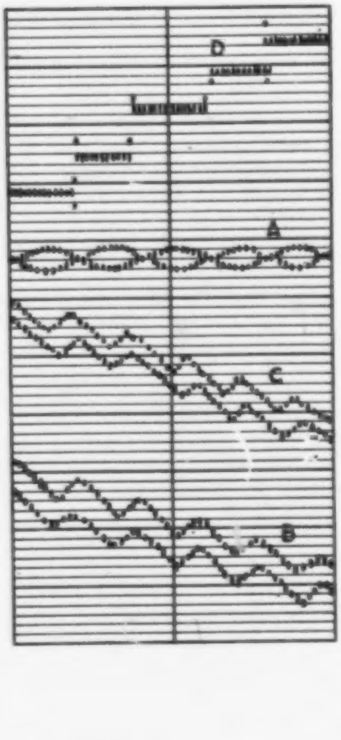
Records A, B, and C in figure 7-9 may indicate that the escape wheel is out-of-round or has a burr on its pinion. Such a condition may cause a change 10 times per minute. Record A may indicate that the wheel is out-of-round or not exactly centered in its arbor. Record B may show that the pinion alone is defective and that the escapement is not affected thereby. Record C may indicate that the pivot or arbor is causing the trouble. Record D indicates that the escape wheel has a mutilated tooth but that adjustment of the watch is otherwise acceptable.

In figure 7-10 you see record A of a watch which shows a condition of overbanking (excessive balance motion); and also record B, which shows a record of the same watch after a new mainspring was installed.

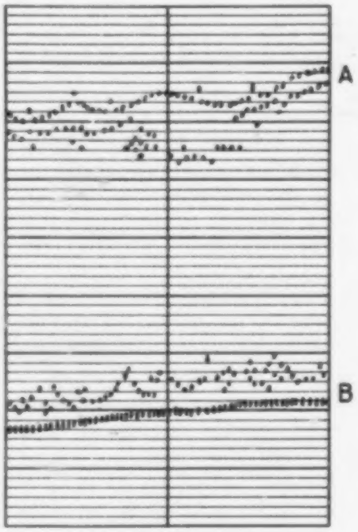
Study next figure 7-11, in which record A may indicate that the watch has a loose pallet stone on the discharge side. Record B may indicate that the watch has a loose banking pin on



91.264
Figure 7-10.—Record of a watch with excessive balance wheel motion (before and after correction).



91.263
Figure 7-9.—Record of a watch with an escape wheel out-of-round or with a burr on its pinion.



91.265
Figure 7-11.—Record of a watch with defective locking of the escape wheel.

the receiving side. In addition to these defects, the record may show excessive slide in the escapement. The upper or lower line of the record may be an indication of the side on which the slide must be reduced. Proper adjustment of the escapement will bring the lines together.

ADJUSTMENTS FOR TEMPERATURE

A balance wheel of a good watch today is made of solid, monometallic metal which requires no temperature compensation (adjustments). The same thing is true for a good clock. The wheel is made of brass or beryllium alloy. The hairspring used with the balance wheel is also made of metal or an alloy (nickel, steel, chromium) which is practically insensitive to normal temperature changes.

Because many watches and clocks in use today do not have the newest types of balances, it is necessary that you know how to adjust them in order to compensate for temperature changes. The first balances in watches did not have ANY MEANS built into them to compensate for changes in high and low temperatures. As a result, becasue metal expands when hot and contracts when cold, the balance wheel and hairspring (made of soft metal) expanded in diameter during hot weather and decreased in diameter during cold weather. The increase and decrease in the diameter of the balance wheel and hairspring made the watch run slower in hot weather and faster in cold weather.

Watch manufacturers then conceived the idea of making a balance wheel with built-in compensation for changes in temperature. They made the rim of the balance wheel of fused steel and brass, with the brass portion (about 3/5 of the total thickness) on the outside. Because the coefficient of expansion of brass is greater than that of steel, the free ends of a cut balance wheel made of these metals curl IN and OUT slightly with changes of temperature and therefore slightly change the diameter of the balance wheel.

The ends of the balance wheel are forced outward during cold weather.

This type of balance wheel (bimetallic) was more satisfactory than the monometallic type, but the free ends were not forced inward to the same extent in INCREASED temperature as they were moved outward with DECREASED temperature. In other words, the bimetallic balance did not entirely meet the error in rate of running of a watch in hot and cold temperatures; so, other means were devised for obtaining a better compensation for temperature changes.

Temperature compensation in watches with bimetallic, cut balance wheels is obtained by balance screws in the rim. There are usually twice as many holes in the rim of the wheel as there are screws; so if the rate of the watch varies in different temperatures, you can compensate for the variation by moving the screws in opposite pairs closer to or farther away from the open ends of the balance. If a watch loses time in hot weather, shift opposite parts of screws TOWARD the open ends of the balance; if the watch gains in hot temperatures, shift opposite pairs of screws AWAY from the open ends of the balance.

ISOCHRONAL ADJUSTING

An isochronal hairspring applies torque on the balance staff directly proportional to the angle through which the balance turns—the energy stored in the hairspring by the impulse from the escapement releases itself in the form of equal torque on the balance staff. As used here, equal torque means that all of the energy stored in the hairspring is utilized in returning the balance wheel to its neutral position—no energy is lost to side thrust on the balance staff pivots. The purpose of isochronal adjustments, therefore, is to establish the force of the hairspring in a manner that will ensure an equal rate for the watch in the HIGH and LOW arcs of motion.

If a watch is properly adjusted for isochronism, it will run uniformly for 24 hours. It may gain or lose during this period, but it MUST run uniformly. Bends in the overcoil of a hairspring, affect the isochronal qualities of the spring. Bends in the overcoil of a hairspring when the balance is out of the watch tend to affect the free end (REGULATOR CIRCLE). Bends in the overcoil when the balance is in the watch tend to push the spring against one of the regulator pins. Isochronal adjusting is closely associated to the FINISHING PROCESSES you studied under hairspring manipulation.

CHECKING ISOCHRONAL RATES

With a timing machine, you can check the rate of a watch at 10 different motions, beginning with 1/2 turn and increasing the motion in steps of 1/8th turn through 1 5/8th turns.

Motion of Balance Wheel	Rates in Seconds Obtained in Test Made on			
	Overcoil a	Overcoil b	Overcoil Between b & c	Overcoil c
½ turn	−39	+27	+08	+02
⅝ turn	−32	+20	+05	+02
¾ turn	−24	+14	±00	+01
⅞ turn	−18	+07	−03	±00
1 turn	−15	+03	−05	±00
1⅛ turn	−10	±00	−07	−01
1¼ turn	−07	−01	−09	±00
1⅜ turn	−05	−01	−08	±00
1½ turn	−05	±00	−08	+01
1⅝ turn	−05	+06	−05	+02

91.266X

Figure 7-12. — Rates of watches with different shapes in the overcoils of their hairsprings.

Figure 7-12 shows the watch rates of four separate tests, each made with a different shape of the overcoil in the hairspring. See figure 7-13.

The rates obtained from the four tests are shown in figure 7-14 in which the rates of the watch in seconds for 24 hours are plotted vertically and the motion of the balance wheel is plotted horizontally.

In the first test, the isochronal curve is designated CURVE ESTABLISHED BY OVERCOIL AT a. An analysis of the rates from the first to the fourth test does not definitely establish the overcoil as being located exactly at a, b, or c. This test shows that the portion of the overcoil from c to b is too far away from the balance staff, because the rate is slow in the low arcs and faster in the high arcs.

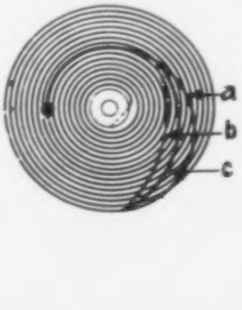


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Figure 7-13. — Position of overcoils for watch rates listed in illustration 7-12.

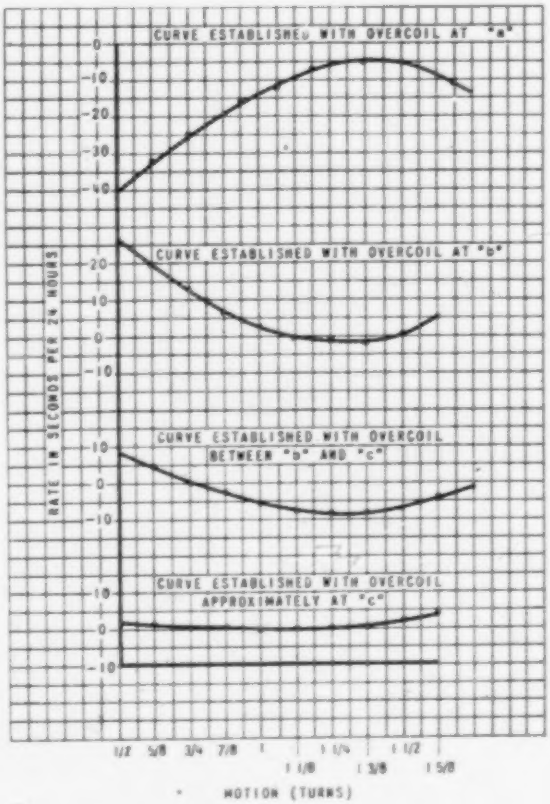

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Figure 7-14. — Chart of watch rates listed in illustration 7-12.

In test number two, the overcoil was bent toward the staff. The isochronal curve for this test is marked CURVE ESTABLISHED BY OVERCOIL AT b. Here the overcoil is TOO CLOSE to the balance staff, because the rate has reversed itself and is fast in the low arcs of motion and slow in the high arcs.

The third test (overcoil between b and c) shows a slight improvement over the second test, but it indicates that the overcoil is still too close to the balance staff.

Observe in illustration 7-12 that the deviation of the rate of the watch is at a minimum with the overcoil at c, which indicates that this overcoil is located close to the theoretically correct position. In other words, for a watch in good condition, with the regulator circle of its hairspring overcoil centered between the regulator pins (tightly closed), the ideal shape and position of the overcoil resemble the overcoil at c in figure 7-13.

ADJUSTING REGULATOR PINS

Always take into consideration the position of regulator pins when you make corrections for isochronal errors. Some watchmakers advocate that isochronal and position errors can be corrected by opening or closing the regulator pins.

As a general rule, the regulator pins of a watch should be ALMOST closed. An opening of 0.0003 inch is necessary to allow the overcoil to slide freely between the pins; but the maximum opening of the pins should not exceed 0.0006 inch. You can check these measurements with a feeler gage, and observe them with a strong loupe. When a watch is in service, opened regulator pins introduce errors into its rate of operation in a vertical position. If the pins are opened when the overcoil is centered between them, the watch LOSES more and more as it runs down. If the overcoil bears MORE on one pin than on the other, the watch GAINS more and more as it runs down. Opening the pins may also damage the value of the regulator.

You can test the effect of OPENING and CLOSING the regulator pins of a watch on its isochronal rate in the same manner as explained above for bending the overcoil. Study figure 7-15, which gives the rates of a watch with the regulator pins set in four positions. Note that for the first test the pins were CLOSED TIGHT. While you are studying this illustration, compare the results of the test with the curves drawn on the chart in figure 7-16. The rates of the twelve motions of the balance wheel are shown by the four curves on the chart.

The motion of the balance wheel is plotted horizontally and the RATES are plotted vertically. The time variation is given in minutes and seconds, and each vertical interval on the chart represents 15 seconds per 24 hours.

An analysis of the results of the tests shows that the first test (curve No. 1, pins closed) gave the best isochronal rate. The second test (curve No. 2, pins opened 0.0006 inch) shows that the rate in the lower arcs of motion is relatively

Motion of Balance Wheel	Rates in Minutes and Seconds Obtained in Tests Made on Overcoil with Regulator Pins			
	(1) Closed Tight	(2) Open 0.0006"	(3) Open 0.002"	In Contact With Hairspring at End of 90° Swing
1/4 turn	+00.21	+00.03	−3.54	−8.45
3/8 turn	+00.15	00.00	−2.42	−8.45
1/2 turn	+00.12	−00.03	−1.36	−7.36
5/8 turn	+00.12	00.00	−1.24	−7.24
3/4 turn	+00.12	+00.03	−1.12	−6.54
7/8 turn	+00.12	+00.03	−1.06	−6.27
1 turn	+00.12	−00.05	−0.54	−6.18
1 1/8 turn	+00.12	+00.06	−0.42	−6.07
1 1/4 turn	+00.12	−00.06	−0.36	−5.36
1 3/8 turn	+00.12	+00.07	−0.30	−4.48
1 1/2 turn	+00.12	+00.09	−0.24	−3.51
1 5/8 turn	+00.12	+00.12	−0.18	−3.15

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Figure 7-15.—Watch rates with regulator pins in four different positions.

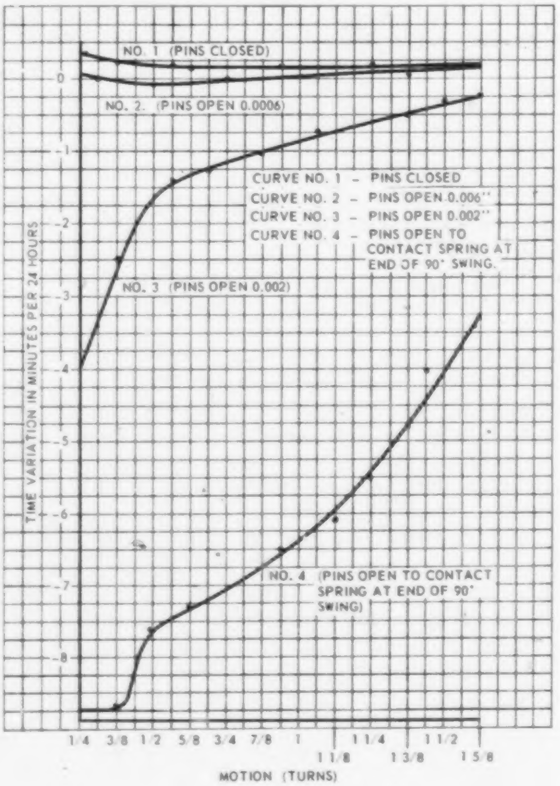

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Figure 7-16.—Chart of watch rates with regulator pins at four different positions.

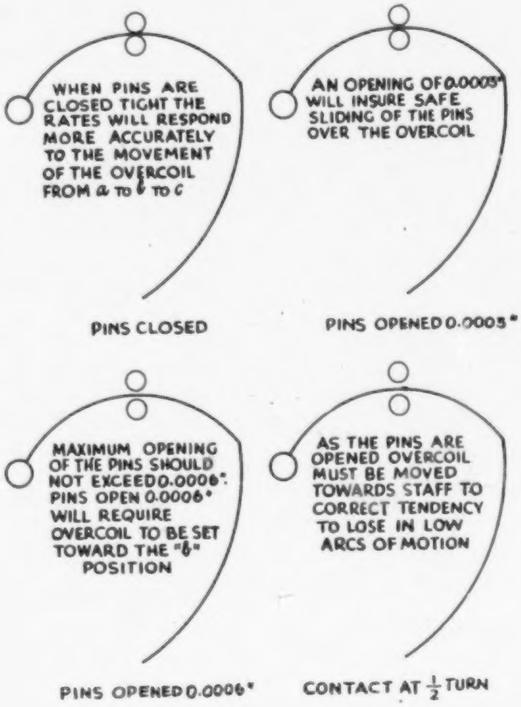
slower than the rate in those same arcs with the pins closed. The third test (curve No. 3, pins opened 0.002 inch) shows the effect on the isochronal rate of opening the pins wider. The fourth test (curve No. 4) shows the rate of the watch when the pins are open to contact the spring at the end of a 90° swing. Contact between the hairspring and regulator pins results in an extremely slow rate in the low arcs of motion and a rapidly increasing rate in the high arcs, caused by the shortening of the spring by this contact.

If the regulator pins are opened more than the amount for any of the tests just described, the watch has a slower rate, especially in the low arcs of motion. If the points are left WIDE OPEN, the watch loses about 10 minutes per day. It is best to open the regulator pins a very small amount, usually no more than 0.0003 inch.

Modern watches are adjusted for isochronism by manufacturers and no further adjustment is required unless the watch is seriously damaged. When you must adjust a watch for isochronal errors, therefore, follow this rule: KEEP THE PINS ALMOST CLOSED; AND HAVE THE OVERCOIL HIT BOTH PINS WITH EQUAL FORCE. Study figure 7-17 which shows the overcoil between the pins in four different positions.

POSITION ADJUSTMENTS

You will have to adjust for POSITION almost every watch or clock you repair. In order for the balance and hairspring to act as a perfect vibrating system, the balance wheel must be affected only by the energy stored in the hairspring. When there is no friction on the balance pivots and the balance wheel is free to oscillate without influence from an outside force (such as the escapement), the only conditions (omitting temperature) which affect the action of the balance wheel are GRAVITY and MAGNETISM. These conditions, however, may affect the balance of a watch and its timekeeping qualities and make corrective adjustments necessary. Gravity always has some effect on the vibrating of a watch; and if the watch is OUT OF POISE, the force of gravity accentuates this condition and causes appreciable changes in the rate of the watch. These rate changes are particularly noticeable in the vertical positions (12, 6, 9, and 3 UP), the ones generally used for testing.


WHEN PINS ARE CLOSED TIGHT THE RATES WILL RESPOND MORE ACCURATELY TO THE MOVEMENT OF THE OVERCOIL FROM a TO b TO c
PINS CLOSED
AN OPENING OF 0.0005" WILL INSURE SAFE SLIDING OF THE PINS OVER THE OVERCOIL
PINS OPENED 0.0005"
MAXIMUM OPENING OF THE PINS SHOULD NOT EXCEED 0.0006". PINS OPEN 0.0006" WILL REQUIRE OVERCOIL TO BE SET TOWARD THE "b" POSITION
PINS OPENED 0.0006"
AS THE PINS ARE OPENED OVERCOIL MUST BE MOVED TOWARDS STAFF TO CORRECT TENDENCY TO LOSE IN LOW ARCS OF MOTION
CONTACT AT $\frac{1}{2}$ TURN

91.271X

Figure 7-17. — Overcoil with regulator pins closed and opened (varying amounts).

The names of watch positions used for testing are as follows:

1. Vertical:
    a. 12 UP is PENDANT UP (PU).
    b. 6 UP is PENDANT DOWN (PD).
    c. (UP is PENDANT RIGHT (PR).
    d. 3 UP is PENDANT LEFT (PL).
2. Horizontal:
    a. DIAL UP (DU).
    b. DIAL DOWN (DD).

Watches with the best movements are usually adjusted to five positions: PU, PR, PL, DU, and DD. Navy clocks are adjusted to TWO positions: DD and PU.

HORIZONTAL POSITION ADJUSTMENTS

You can use a timing machine to test the running of a watch in the horizontal positions

(DU and DD), or you can check it for 24 hours in each position with a timepiece of known accuracy. CORRECT ANY VARIATION between the DIAL UP and DIAL DOWN positions. There are many faults, in fact, which will cause a variation between the running of a watch in the dial up and dial down positions, some of which are:

1. Dirt or thick oil in balance hole jewel(s).
2. Burred or marred balance pivot.
3. End of one balance pivot flat or rough.
4. Balance pivot bent.
5. Ends of balance pivots of different form.
6. Hairspring rubs on balance arm, stud, or regulating pins.
7. Hairspring not level.
8. Overcoil rubs center wheel.
9. Overcoil rubs under balance cock.
10. Balance pivots fit too tight in jewels.
11. One balance pivot has excessive side shake.
12. Escape or pallet pivot bent or damaged.
13. Balance endstone pitted or out of flat.
14. Overcoil rubs outside coil where it curves over the spring.
15. Balance arm touches pallet bridge.
16. Balance screw touches balance bridge.
17. Safety roller rubs plate or jewel setting.
18. Fork rubs impulse roller.
19. Roller jewel too long; rubs on guard pin.
20. Pivot(s) dry.

After you correct all faults that interfere with the accurate running of a watch in the horizontal positions, you must then adjust the arcs of motion in the vertical positions to equal the rate made by the horizontal positions.

VERTICAL POSITION ADJUSTMENTS

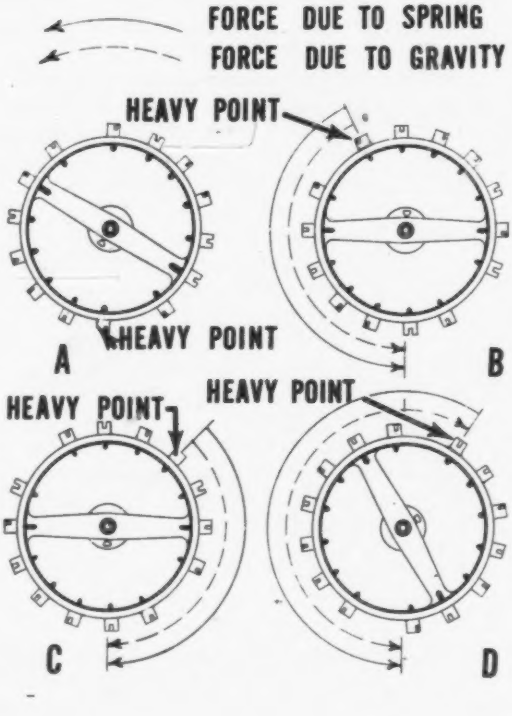
The factor which probably has the most effect on the timekeeping of a watch in the vertical positions is poise, which requires detailed consideration at this point.

The purpose of POISING a balance wheel is to distribute the mass (weight) of the wheel evenly around the axis of rotation, so that the effect of the force of gravity is minimized. Weight, by definition, is merely the amount of force exerted on an object by gravity. It is obvious, therefore, that if there is a point on the rim of a balance wheel which is heavier than other points, that point will be pulled down. In short, the balance wheel (without the influence of the hairspring or any other force) rotates until the heaviest part finally settles at the lowest point.

How Gravity Affects Poise Error

The effect of gravity on the poise error of a watch is shown in figure 7-18. Assume that a balance wheel is out-of-poise because of a HEAVY POINT so located that when the balance staff lies in a horizontal plane (watch in PENDANT UP position) and is at rest in the zero position, the center of gravity in the balance wheel is directly below the rotation center (part A, fig. 7-18). If the balance wheel is in motion but moving LESS THAN one turn (less than 180° each side of the neutral (zero) position) when the balance wheel comes to rest at the end of the outward swing, the heavy point will be near the top of the wheel (part B, fig. 7-18). At this point, all energy in the vibrating assembly is potential energy stored in the hairspring.

As the energy in the hairspring is transferred into motion, the force of gravity acting on the heavy point adds additional energy to the balance



91.272X
Figure 7-18.—Forces of hairspring and gravity acting in different arcs of motion.

in the same direction as the energy of the hairspring. This extra energy intensifies the force exerted on the balance wheel and makes the watch run faster.

Now assume that the heavy point on the rim has reached the bottom of its path, when all the energy is stored in the balance wheel — none in the hairspring. As the balance wheel moves past the neutral position, part of this energy is stored in the hairspring and part of it is used in raising the heavy point (part C, fig. 7-18). The balance wheel passes through a shorter arc of motion; that is, it takes less time to complete an oscillation and the watch runs faster.

If the balance wheel is in motion and moving through MORE THAN one turn (over 180° each side of the neutral position), as illustrated in part D of figure 7-18, during the first part of its path (until heavy point is lifted 180°) gravity is opposing the action of the hairspring. During this arc of motion the balance wheel moves more slowly, as if acted upon by a weaker hairspring. After it passes the 180° point, it moves more rapidly down toward the zero point, because the effect of the hairspring is strengthened by the energy added by the HEAVY point. In other words, the effect of gravity on the heavy point causes a slower motion in the first portion of the path and a faster motion in the second part.

Experience has shown that a swing of about 1 1/4 turns of a balance wheel is the ideal motion, because small out-of-poise errors are neutralized at this point. Few watches maintain this motion for a 24 hour period, however, so it is necessary to poise watches. When you are locating the theoretical heavy point of a balance during the poising operation, make certain that the watch is less than HALF WOUND. Yo already learned that you can redistribute the weight on the rim of a balance wheel by undercutting screws, moving screws, or adding weight to screws with washers.

Tests for Position Errors

An out-of-poise watch with a heavy point in the position of part A of figure 7-18 was tested for position errors (changes of rate under varying arcs of motion). The rates of motion from 240° to 444° were taken in successive steps at two positions, 12 UP and 6 UP. The results of this test with the watch running at 11 different arcs of motion are listed in figure 7-19.

Figure 7-20 depicts graphically the rate variation of the watch tested in different vertical positions (arcs of motion). Observe the amount of turn for each curve. Curve No. 1 shows that the two positions which have the greatest variation in rate are PL and PR. The distances of the extreme points on curves No. 1 and No. 3 from the horizontal axis indicate that the watch is out-of-poise. Curve No. 3, representing the results of the test after the motion of the balance wheel was reduced from 1 1/4 turns to 7/8 turn, shows that with this change in the arc of motion all the fast rates have changed toward SLOW and the slow ones have changed toward FAST.

The variations in rate of a watch in all vertical positions (with different arcs of motion) can always be observed by plotting a chart of the type shown in figure 7-20. In practice, however, the quickest way to locate a poising error is to use a poising tool.

Correction of Heavy Point Poise Error

If you use rate-variation curves to find the exact location of the HEAVY POINT on a balance wheel, note first the positions which show the faster rate. Curve No. 3 in figure 7-20, for example, shows the greatest variation in rate at the PR position. This indicates, therefore, that the HEAVY POINT is at PL. To correct this poise error, proceed as follows:

1. Let the mainspring down.
2. Place the watch movement in a vertical position, PU, on the workbench, with the balance wheel facing front.
3. Make a drawing of the balance wheel, showing LINE OF CENTERS, location of balance arms, and the roller jewel. Indicate the position of the heavy point at the bottom of the balance wheel.
4. Wind the mainspring slightly, enough to keep the balance wheel moving at 1/2 turn. This causes the heavy point to move 90° to the left and to the right.

How Heavy Point Affects Watch Rate

When a watch is in the PENDANT UP position and has a heavy point at the BOTTOM of its balance wheel, it is apparent that:

1. If the motion is less than 444°, the rate is faster in the PENDANT UP position than in the PENDANT DOWN position.

Position	Rate (in seconds) at Arc of—										
	270°	290°	330°	350°	360°	380°	400°	420°	438°	442°	444°
12 UP	+ 57.0	+ 46.0	+ 37.0	+33.0	+12.6	−02.8	−01.5	−08.8	−15.5	−17.8	−17.4
6 UP	− 74.4	− 71.6	− 64.0	−59.0	−44.2	−34.6	−27.0	−23.8	−18.0	−18.8	−17.4
Difference	+131.4	+117.6	+101.0	+92.0	−56.8	+31.8	+25.5	+15.0	+02.5	+01.0	00

91.273X

Figure 7-19. — Differences between watch rates for varying arcs of motion.

2. If the motion is over 444°, the rate is faster in the PENDANT UP position than in the PENDANT DOWN position.

In other words, when the force of the hairspring and the effect of gravity on the heavy point both act in the SAME direction, the rate of the watch is fast. When the effect of gravity on the heavy point is in the OPPOSITE direction from the force of the spring, the rate of the watch is slow.

From the previous discussion, it appears evident that when the HEAVY point is at right angles to the PU position the effect of gravity on this point does not affect the rate in the PU or in the PD POSITIONS, for the PL and PR positions are then on the axis of greatest vibration. To determine the rate variations of a watch in the various vertical positions, we must measure the rate in each position. The results of such measurements are shown in figure 7-21.

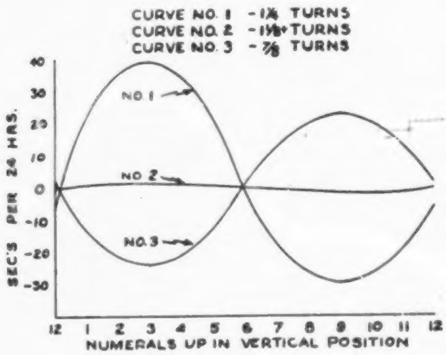


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Figure 7-20. — Chart of watch rate variations in different vertical positions (three arcs of motion).

The measurements listed in figure 7-21 were taken with a timing machine for all 12 positions. The arcs of motion used for the test were 1 1/4 turns, 1 1/4 minus turns, and 7/8 turn. A comparison of the rates measured with those of the opposite points UP gives the results tabulated in the VARIATION column. For example, at the PU position the watch rate is 6 seconds slow (-06) per 24 hours, but at the PD position the rate is 1 second slow (-01) per 24 hours. The watch tested, therefore, is running 5 seconds slower each day in the PU position than in the PD position, giving a variation in rate of 5 seconds. In the PR position the rate of the watch is

WATCH RATES: RATES AND RATE VARIATION (Seconds Per 24 Hours) AT VERTICAL POSITIONS FOR DIFFERENT ARCS OF MOTION

Position (up)	1¼ Turn (450°)		1¼ Minus Turn (444°)		⅞ Turn (315°)	
	Rate (seconds)	Variation (seconds)	Rate (seconds)	Variation (seconds)	Rate (seconds)	Variation (seconds)
12	−06	−05	0	0	+02	+01
1	+21	+39	+01	+01.5	−13	−25
2	+35	+61	+01.5	+02.5	−21	−36
3	+39	+69	+01.5	+03.5	−24	−42
4	+34	+61	+01	+03	−21	−36
5	+22	+41	+00.5	+02.5	−13	−26
6	−01	+05	0	0	+01	−01
7	−18	−39	−00.5	−01.5	+12	+25
8	−26	−61	−01	−02.5	+15	+36
9	−30	−69	−02	−03.5	+18	+42
10	−27	−61	−02	−03	+15	+36
11	−19	−41	−02	−02.5	+13	+26
12	−06	−05	0	0	02	+01

91.274X

Figure 7-21. — Watch rates (and rate variation) at vertical positions for different arcs of motion.

minus 30 seconds per 24 hours, and in the PL position, the rate is plus 39 seconds, giving a variation in rate between the PL and PR positions of plus 39 seconds (variation of minus 69).

5. Wind the mainspring a little tighter, enough to increase the arc of motion to the extent necessary to raise the heavy point to a 7/8 turn; then raise the heavy point (by winding) to 1 turn. Wind the mainspring tighter. Increase the motion of the balance gradually until it reaches its maximum swing (444°). When the heavy point reaches a point of 42° (444 minus 360 equals 84, and 84 divided by 2 equals 42) beyond the vertical axis, it arrives at a point where the gaining effect caused by gravity balances the losing effect present up to the vertical line.

6. Remove the balance wheel and take off the collet and hairspring.

7. Put the balance wheel in poising calipers or a poising tool. When you do this, gravity pulls the heavy point to the bottom.

After you poise the balance wheel, test the rate of the watch in vertical positions with a timing machine. If the rates of the watch for the different arcs of motion are as illustrated by the curves in figure 7-22, you have satisfactorily adjusted the watch for position.

Another Method of Testing and Adjusting

Another way to test a watch for vertical position errors is to check it against an accurate watch over a 24-hour period in the DIAL UP, PENDANT UP, and PENDANT DOWN positions. After completion of the three-position test, the recorded rates may be as follows: dial up, 6 seconds fast for 24 hours; pendant up, 4 seconds slow for 24 hours; and pendant down, 26 seconds slow for 24 hours. This rate shows that with the pendant up it is 10 seconds slower than with the dial up; and with the pendant down it is 32 seconds slower than with the dial up. The mean for this rate is 21 seconds, the amount the SHORT ARCS ARE SLOW. The hairspring coils do not open and close equally in both vertical positions because of an improperly formed overcoil which does not hold the hairspring concentrically. To make correction, reform the overcoil until the rates of the vertical positions are equal. The arcs of motion are then equal.

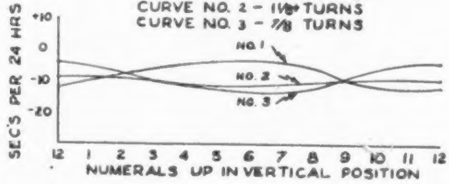

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Figure 7-22. — Chart of watch rate variations (poise error corrected).

After completing the three-position test, the rates of the watch may be: dial up, 3 seconds FAST for 24 hours; pendant up, 11 seconds FAST for 24 hours; and pendant down, 5 seconds SLOW for 24 hours. This shows that with the pendant UP it is 8 seconds faster than with dial UP; and with the pendant DOWN, it is 8 seconds slower than with the dial UP. The mean of the two vertical positions is equal to that of the horizontal. The difference between pendant UP and pendant DOWN shows a slight error in poise. The losing rate (pendant down position) signifies a heavy point at the top of the balance when it is running in that position. To correct for the heavy point, turn the meantime screw of the pendant down position a quarter turn clockwise. If this screw is too close to the rim, turn the meantime screw of the pendant up position a quarter turn counterclockwise.

HORIZONTAL VERSUS VERTICAL POSITION RATE

A watch perfectly adjusted in the horizontal position always runs a little slow in the vertical positions, because of friction from the two balance pivots running on the side of each hole jewel and the increased effect of gravity on the hairspring. The difference in rate is usually about 15 seconds. The vertical rate can be made faster by closing the regulator pins, thereby decreasing the effect produced by a longer hairspring. Do NOT allow the vertical motion of a watch to fall below one full turn at the end of 24 hours. As indicated previously in this chapter, an arc of motion of 1 1/4 turns during the day for the vertical positions is desirable.

OTHER POSITION-ADJUSTING METHODS

Some other methods for adjusting the rate of a watch (exclusive of corrections for poise error) are:

1. Replacing a worn or damaged balance staff.
2. Cleaning and oiling balance staff jewels.
3. Moving regulator pins IN or OUT.
4. Removing obstruction to the FREE movement of the hairspring.
5. Using a different angle for pinning the hairspring in the collet.
6. Changing the shape of the overcoil.

As you doubtless have observed, some of the above methods for adjusting the rate of a watch are a restatement of what you have previously learned in this text. Always use your total knowledge and experience, therefore, when you select a method(s) for adjusting rate. In one instance, a single method is adequate; in other instances, a combination of methods may be required to properly regulate the rate of a watch.

PUTTING A WATCH IN BEAT

A watch is in beat when the hairspring is unstressed and the roller jewel is midway between the two banking pins (fig. 7-23). A watch is out of beat when the hairspring is attached to the balance staff in such a position that (when unstressed) it holds the roller jewel a number of degrees away from the line of centers.

To determine whether a watch is in beat, hold it in the dial down (DD) position and use a beat tool to stop the balance; that is, try to get an escape wheel tooth to stay locked on either the R or the L stone of the pallet. You can best do this by allowing a balance screw to hit against the beat tool. If you cannot stop the motion of the balance wheel by this action, the watch is in beat.

If you can stop the balance by the action just described, test for the direction of the starting push. You can do this by carefully bringing a beat tool into contact with a balance screw. When a slight touch or push releases the escapement and starts the balance in motion, the direction of the balance is the correct direction of the starting push. If you had put the beat tool on the opposite side of the same screw and pushed, you would have applied the push in the WRONG direction and the escapement would not have been released. It is the STARTING PUSH which causes the roller jewel to hit against the fork slot of the pallet which, in turn, unlocks the tooth of the escape

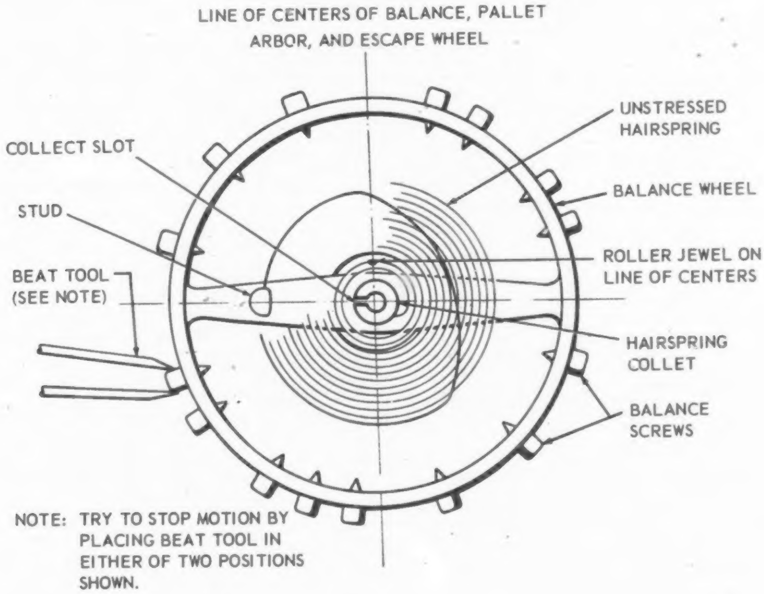

LINE OF CENTERS OF BALANCE, PALLET ARBOR, AND ESCAPE WHEEL
COLLECT SLOT
STUD
BEAT TOOL (SEE NOTE)
UNSTRESSED HAIRSPRING
BALANCE WHEEL
ROLLER JEWEL ON LINE OF CENTERS
HAIRSPRING COLLET
BALANCE SCREWS
NOTE: TRY TO STOP MOTION BY PLACING BEAT TOOL IN EITHER OF TWO POSITIONS SHOWN.
91.277X

Figure 7-23.—Position of roller jewel (jewel pin) of a watch in beat.

wheel. You can therefore decide in this manner on which side of the line of centers the roller jewel is when you arrest the motion of the balance wheel. When the hairspring is unstressed, the roller jewel lies on this side.

To correct the error just explained and bring the watch into beat, use one of the following methods:

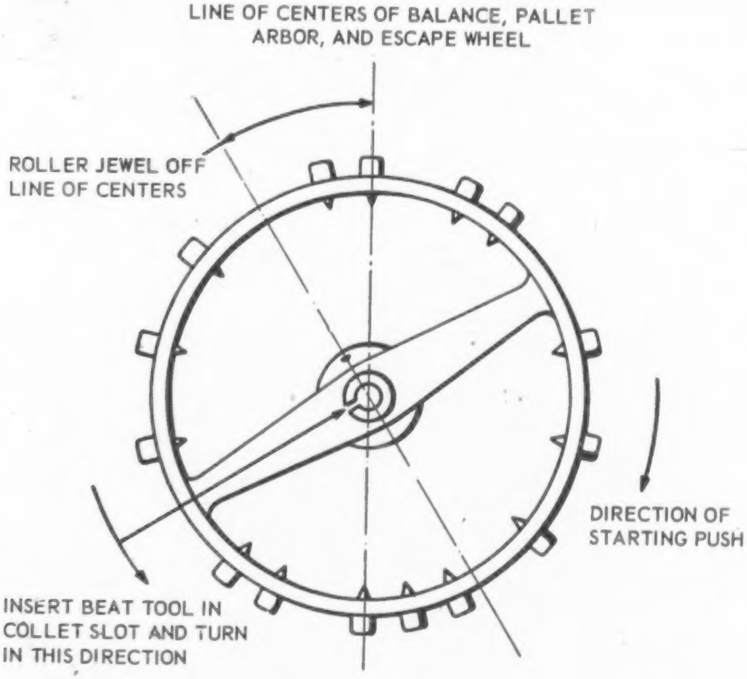
1. Hold the collet by inserting a beat tool into its slot. See figure 7-24. Then turn the balance wheel in the same direction as the starting push.
2. Hold the balance wheel still and use a beat tool to move the collet in the opposite direction of the starting push.

Only through experience will you learn HOW MUCH TO MOVE THE COLLET on the balance staff in order to put a watch in beat.

Figure 7-24 shows a balance wheel which was stopped with a beat tool, with the pallet locked on the L stone. The roller jewel, as indicated, is positioned to the left of the line of centers. This watch is OUT OF BEAT, and the error can be corrected by one of the two aforementioned methods. Either method so shifts the collet that the roller jewel is on the line of centers.

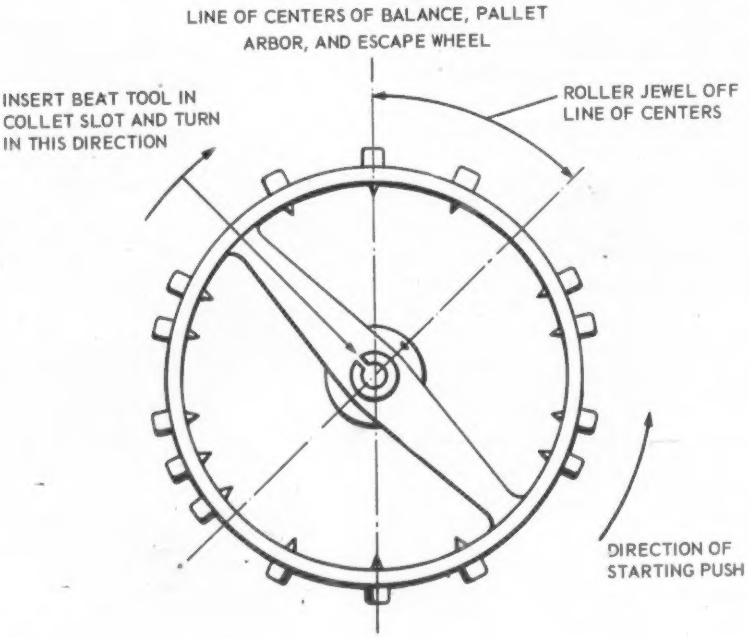
Study next figure 7-25, which shows a balance wheel stopped, with the pallet locked on the receiving (R) stone. In this case, the roller jewel is positioned to the right of the line of centers (balance nearest you; escape wheel fartherest away). This indicates that the WATCH IS OUT OF BEAT, and that the roller jewel will be to the right of the line of centers when the hairspring is unstressed. By using one of the previously mentioned methods, you can shift the collet sufficiently with a beat tool to bring the roller jewel to the line of centers, thereby putting the watch in beat.

When you cannot reach the collet when the balance wheel is in the watch, to prevent damage to pivots or the hairspring, remove the balance cock and balance wheel before you attempt to shift the hairspring collet.


LINE OF CENTERS OF BALANCE, PALLET ARBOR, AND ESCAPE WHEEL
ROLLER JEWEL OFF LINE OF CENTERS
DIRECTION OF STARTING PUSH
INSERT BEAT TOOL IN COLLET SLOT AND TURN IN THIS DIRECTION

91.278X

Figure 7-24.—Using a beat tool to put a watch in beat (roller jewel left of line of centers).


LINE OF CENTERS OF BALANCE, PALLET ARBOR, AND ESCAPE WHEEL
INSERT BEAT TOOL IN COLLET SLOT AND TURN IN THIS DIRECTION
ROLLER JEWEL OFF LINE OF CENTERS
DIRECTION OF STARTING PUSH

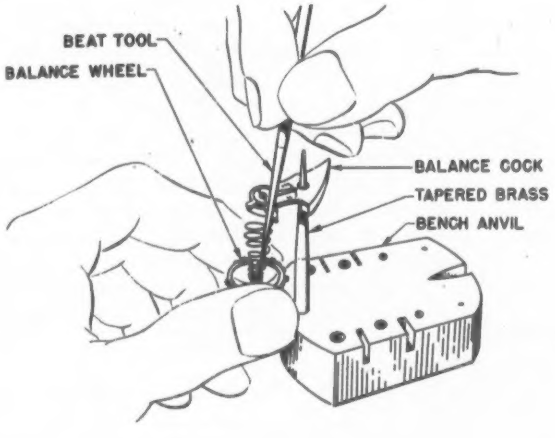
91.279X

Figure 7-25. — Using a beat tool to put a watch in beat (roller jewel right of line of centers).

Illustration 7-26 shows a balance cock on a tapered piece of pegwood or brass inserted in a hole of a bench anvil. With the balance cock and suspended balance wheel in this position, hold the balance wheel with the left hand and insert a beat tool held in the right hand down through the coils of the spring and into the collet slot. Then turn the collet in the direction necessary to put the watch in beat (clockwise when a counterclockwise movement of the balance wheel is desired, and vice versa).

FINAL REGULATIONS

Final regulations of a watch are the last minute regulations made by moving the regulator toward FAST or SLOW, as required. A watch may keep perfect time in the shop but fail to keep good time when in use. This may be caused by changes in temperature, irregular winding, jolts, or other adverse conditions. For these reasons, final regulations must be given a watch to meet the conditions under which it is (or will be) used.


BEAT TOOL
BALANCE WHEEL
BALANCE COCK
TAPERED BRASS
BENCH ANVIL

91.280X

Figure 7-26. — Turning hairspring collet with beat tool (hairspring fastened to balance cock).

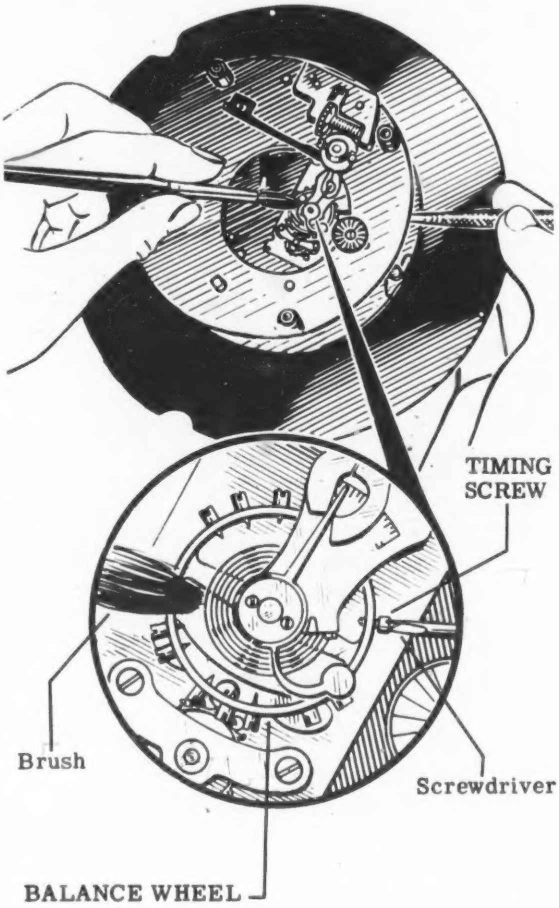
If a watch fails to keep good time after you make all the adjustments possible by moving the regulator, a weak mainspring may be causing trouble, or adjustments on the balance wheel are necessary; that is, adjustments on the meantime screws, or moving the positions of these screws.

A newly-overhauled watch may gain or lose several minutes per day, but a complete turn IN or OUT of opposite pairs of meantime screws (sometimes considerably less than than a full turn) is sufficient to make the watch keep accurate time.

CLOCK TESTING AND ADJUSTING

The following discussion is the recommended procedure for adjusting a clock with a timing machine, and also for giving it a performance test. Proceed as follows:

1. Set the clock regulator to the exact center position between F (fast) and S (slow).
2. Clamp the clock movement on the timing machine (fig. 7-1). NOTE: ALWAYS TIME AND TEST a clock movement in its normal operating position—vertical position with the 12 (or 24) numeral up.
3. Following the manufacturer's instructions, operate the timing machine and note the 24-hour error indicated on the chart recording.
4. Adjust the two meantime (timing) screws to correct the error in rate, as illustrated in figure 7-27. (Meantime screws have smaller heads than the other screws and are located close to the ends of the balance arms.) One complete turn of the timing screws is equivalent to about 100 seconds per day. If the chart shows the clock is gaining time, turn the timing screws OUT; if the recording shows the clock is losing time, turn the timing screws IN. Turn both timing screws the same amount in the same direction. If you cannot bring the clock into correct time by turning the timing screws, make necessary adjustments in the weight of the balance wheel.
5. If the clock is losing time, undercut any two opposite balance screws (or file out the slots) by exactly the same amount. If the clock is gaining time, add timing washers (equal weight) to two opposite balance screws.
6. Place the clock in the timing machine again and adjust the timing screws until the chart recording shows neither gain nor loss of time.



91.281
Figure 7-27.—Adjusting two meantime screws on a clock balance wheel.

When you have the clock keeping perfect time, give it a performance test to make certain that the escapement adjustments were adequate, and to check the accuracy of the timing screw adjustments.

Make the performance test with the clock in a vertical position and at normal room temperature (68° to 72° F). Check the clock against a standard-frequency comparing clock, observing the daily error of the clock. Make notations of dial errors of successive readings. If these dial errors are recorded daily, the rate is indicated by the time GAINED or LOST per day. If

1 DATE	2 DIAL ERROR + = Fast - = Slow		3 DAILY RATE (Daily Error)	4 AVERAGE (Daily Error)	5 DEVIATION OF DAILY ERROR (col 3-col 4)	REMARKS
	Min.	Sec.	Sec.	Sec.	Sec.	
July 1972						
13	-0	03				Started and set 3 seconds slow
14	-0	10	-7	-10	+3	
15	-0	18	-8	-10	+2	
16	X	X	X	X	X	Not checked
17	-0	37	* -10	-10	0	* Two-day average
18	-0	49	-12	-10	-2	
19	-1	1	-12	-10	-2	
20	-1	15	-14	-10	-4	

Weekly error Jul 14-20 = 1 min 15 sec -03 sec = 1 min 12 sec = 72 sec. Average daily error = 10-2/7 sec = 10 sec.

91.282

Figure 7-28. — Weekly performance chart of a clock tested with a timing machine.

observations are unavoidably checked more than one day apart, reduce the rate to a 24-hour basis by dividing the difference in dial errors by the number of days involved. See figure 7-28. Unusual conditions should be noted in the REMARKS COLUMN of this chart, in order that they may be taken into consideration when you determine whether the clock has passed its test.

Other factors besides the daily rate must also be taken into consideration when you try to prove the timekeeping qualities of a clock. If a clock gains exactly 15 seconds per day, it is an excellent timekeeper, because this error can be corrected by slightly slowing down the clock with the regulator. On the other hand, if a clock gains 5 seconds one day and loses 5 seconds the NEXT day, it is NOT AS ACCURATE as the first clock; because the error of this clock CANNOT BE CORRECTED by moving the regulator. Take this factor into account by comparing the daily rate error of the clock with the weekly error divided by 7. A limit must also be placed upon the allowable difference between the two errors.

Refer again to the performance chart. The overall weekly dial error (last entry in column 2 minus the first entry in column 2) must be NO MORE THAN 2 minutes for mechanical clocks, and NO MORE THAN 2 1/2 minutes for boat and deck clocks, for any of the 3 weeks of performance testing. NOTE: Results of one week's testing of clocks are helpful; but if possible, extend the tests over a three weeks' period.

No deviation of daily error in one of the 3 weeks of testing in column 5 of the test chart may be more than ±10 seconds for mechanical clocks and not more than ±15 seconds for boat and deck clocks.

CHAPTER 8

MANUFACTURING

The term MANUFACTURING, as used in this chapter, applies to all instrument parts which you may be required to make in a Navy instrument shop. As a general rule, you will be able to get replacement parts from stock; but in some locations, or during emergency conditions, you may have no alternative but to make new parts for instruments. For this reason and to satisfy the qualifications for advancement, you must know what tools, materials, and methods are used for manufacturing instrument parts. The requirements for advancement to Instrumentman 1 include knowing how to manufacture wheel arbors, balance staffs, and watch and clock thread taps, using a screw plate. Besides, you must know which methods and materials are used for manufacturing pressure gage pinion staffs, arbors, bearing screws, and tachometer backplates. In qualifying for advancement to IMC you must satisfy all the requirements that the IM 1 does and also know materials, tools, and techniques used in manufacturing instrument jewel settings and in repivoting instrument pinion staffs and arbors.

This chapter tells and shows you how to make pressure gage pinion staffs, watch balance staffs, watch stems, barrel arbors, instrument bushings, and jewel mountings. If you know how to make these parts, you will in time learn how to make tools and other instrument parts, such as gravers, pivot drills, plug gages, screwdriver bits, tapered pins, links, gage bushings, bridges, and more. Remember, however, that you can become proficient in making these parts ONLY through experience.

WATCH BALANCE STAFF

The tools you need for making a watch balance staff include the following: alcohol lamp, millimeter micrometer, jeweler's lathe, gravers, No. 30 chuck, polishing block, pin vise, bellmetal slip, iron metal slip, and cement brasses.

MEASUREMENTS FOR NEW STAFF

If you have an old balance staff of the same dimensions as the one you need to make, use it as a sample. There may be occasions, however, when you will not have another staff which can be used as a sample. When this is true, you are compelled to compute the measurements for your new balance staff.

To get the measurements for a new balance staff, proceed as follows:

1. Remove the upper and lower cap jewels of the balance cock and screw the balance cock in position on the pillar plate. NOTE: The balance cock and pillar plate must be parallel. If the balance cock is bent, straighten it before you take any measurements.
2. Measure the distance from the top of the upper hole jewel to the bottom of the lower hole jewel and allow .01 mm extra for the protrusion of the balance pivots.
3. To get the position of the balance wheel, measure from the lower balance hole jewel to the top of the pallet bridge. Add to this measurement the freedom necessary between the balance wheel and the pallet bridge. Special consideration must be given to the correct location of the balance wheel in order to allow for the hairspring and collet.
4. Measure from the lower balance hole jewel to the top of the fork and add the thickness of the impulse roller to get the correct location of the roller seat. Bear in mind that the fork and guard pin are parallel with the pillar plate and that the end of the guard pin must coincide with the center of the safety roller.
5. Get the length of the collet shoulder by measuring the height of the hairspring collet. The other part of the staff is for the upper and lower balance cones and pivots.
6. To determine the diameter of the collet shoulder, select a brass wire with a diameter a little larger than the hole in the collet and

chuck the wire in the lathe. Put enough taper on the wire to make the collet fit friction-tight on it. The position of the collet on the large side of the tapered wire determines the diameter of the collet shoulder.

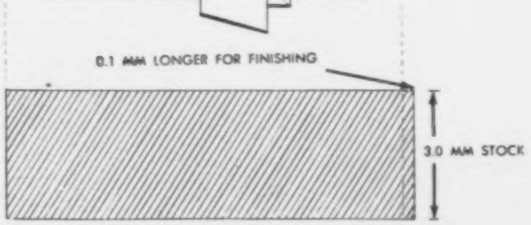
7. Get the diameter of the roller shoulder by doing the following: Turn the roller shoulder on a slight taper until the roller table fits on the small end of the taper. Use an iron metal slip charged with oilstone powder and oil to grind the roller shoulder enough to get the roller table to almost fit up to the roller seat. The space between the roller seat and the roller table MUST NOT EXCEED DOUBLE THICKNESS of the impulse roller. Use pithwood to clean off all traces of oilstone. Polish the roller shoulder with a bellmetal slip charged with diamantine.

METHODS OF TURNING

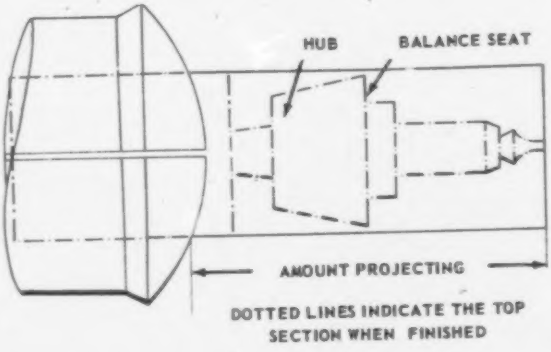
Two methods are generally used for turning a watch balance staff and both are described in some detail in this section. The first method is perhaps used most frequently, but you will learn through experience which one you prefer.

Method No. 1

Select a piece of steel wire stock slightly larger than the greatest diameter of the staff you are making (dimensions on your sketch). Then put the sample balance staff over your piece of steel wire stock, as illustrated in figure 8-1. Next, cut from the wire a piece 0.1 mm longer than your sample staff and harden and temper it, as explained in chapter 14, Instrumentman 3 & 2, NavPers 10193-C.



91.283X
Figure 8-1.—Sample balance staff and wire stock for a new balance staff.



91.284X
Figure 8-2.—Steel wire for new balance staff chucked in a lathe for turning the hub.

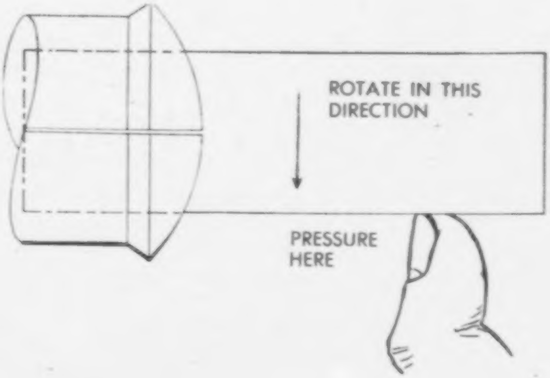
NOTE: While you are making the balance staff, use a micrometer frequently to check the diameter, to make certain that you cut off JUST ENOUGH metal. Always leave enough metal on the part you are making to allow for polishing and finishing.

Now select a No. 30 chuck, which correctly fits the blank, and chuck the blank in the lathe (fig. 8-2), with enough of it projecting from the chuck to enable you to turn the hub of the staff.

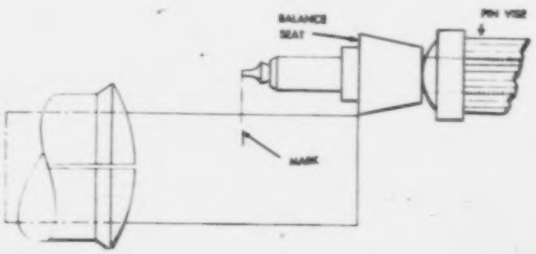
Tighten the chuck just enough to prevent your blank from falling out when the lathe is rotating, so that you can true it with your thumb as it rotates. Study the procedure for doing this in illustration 8-3. Then tighten the chuck fully and examine it with a loupe for trueness.

Continue by clamping the roller shoulder of the sample staff in a pin vise (fig. 8-4) and placing the sample staff parallel with the blank, so that you can mark the balance seat with a graver. Study figure 8-4, noting particularly the position of the balance seat of the sample staff and the location of your mark on the blank.

Now turn on the lathe and start turning the staff with a sharp graver, as shown in figure 8-5. Observe the position of the T-rest and the direction of the cut. Use the point of the graver first to true the steel blank and then use the FULL CUTTING EDGE. To avoid ridges, apply even pressure to the graver and then move it back and forth on the blank.


ROTATE IN THIS DIRECTION
PRESSURE HERE

91.285X
Figure 8-3. — Truing stock chucked in a lathe for making a balance staff.


BALANCE SEAT
PIN VISE
MARK

91.286X
Figure 8-4. — Procedure for marking the balance seat of a new staff.

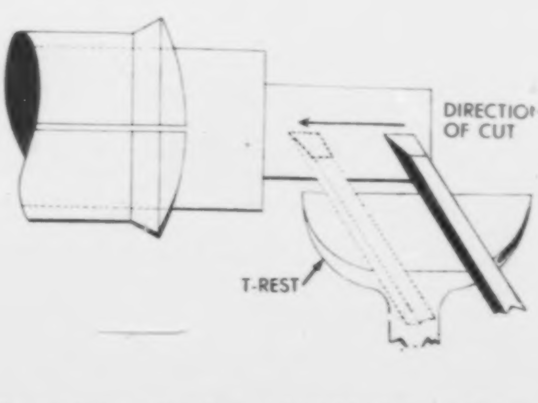

DIRECTION OF CUT
T-REST

Figure 8-5. — Turning a steel blank for a balance staff with a graver. 91.287X

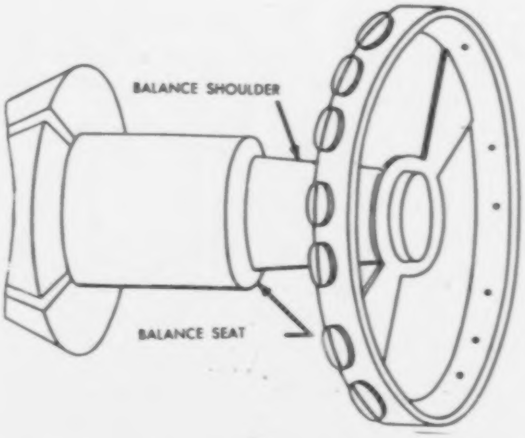

BALANCE SHOULDER
BALANCE SEAT

Figure 8-6. — Turning the balance shoulder of a new balance staff. 91.288X

Use care TO AVOID making the balance shoulder TOO SMALL. Check the diameter with the micrometer.

Turn the stock (shoulder) on a slight taper until the small end fits in the balance wheel hole. Study figure 8-6. Then gradually straighten the stock (taper of balance shoulder) until the balance wheel fits perfectly against the balance seat, as illustrated in figure 8-7. If the fit is

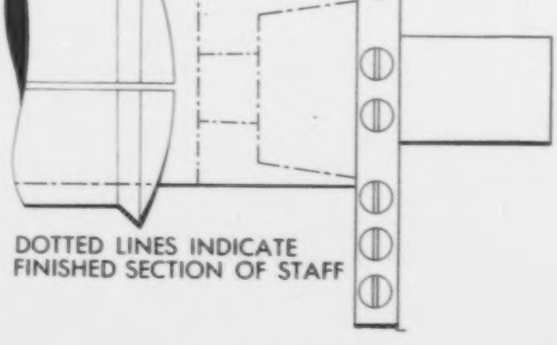

DOTTED LINES INDICATE FINISHED SECTION OF STAFF

Figure 8-7.— Balance wheel fitted on the taper of a new balance staff shoulder. 91.289X

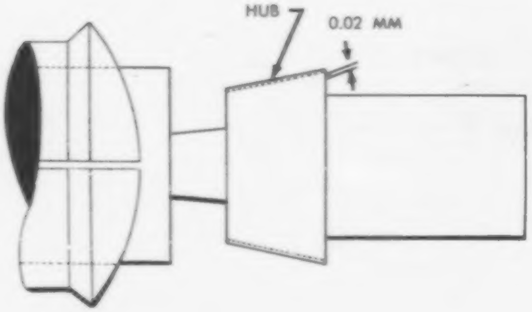


Figure 8-8.—Turning the hub of a new balance staff. 91.290X

too loose, it will cause the balance wheel to be out-of-round when staked; if the fit is TOO TIGHT, it will stretch the balance wheel hole and PERHAPS DISTORT the balance wheel during staking.

Next, turn the hub of the staff .02 mm larger in diameter than the hub of your sample, as shown in figure 8-8.

Position the balance wheel against the balance seat on the stock and mark the stock with the graver, approximately 0.1 mm from the balance arms. This measurement determines the length of the balance shoulder. Study figure 8-9 A and B.

Now start at the mark you made with the graver on the stock and turn the collet shoulder until the diameter is 0.02 mm thicker than the sample (fig. 8-10).

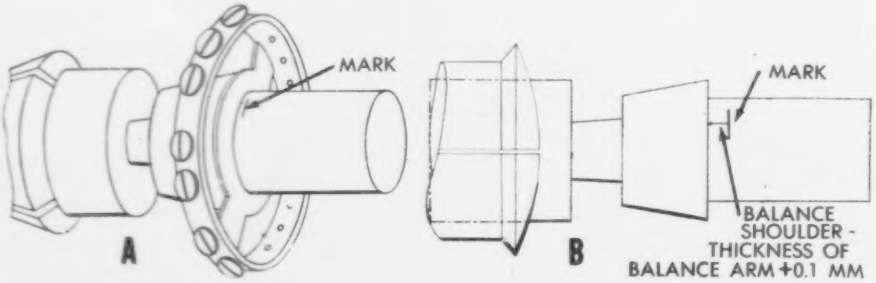
Use a sharp, pointed graver in the manner shown in figure 8-11 to do the undercutting necessary for staking the balance wheel to the staff. Then place the sample balance staff parallel with the blank, so that you can use a graver to lay off the length of the collet shoulder on the blank, as illustrated in figure 8-12.

From the mark you just made on the collet shoulder, turn the upper cone and pivot of the staff. See illustration 8-13. As you turn the pivot, check it frequently with a balance hole jewel of correct size. Continue turning until the pivot starts to fit in the jewel. CAUTION: Stop cutting while there is sufficient metal left for grinding and polishing.

At this point, select a graver with a rounder point (fig. 8-14A) and turn the pivot until it is approximately 2/3 cone and 1/3 pivot, as illustrated in figure 8-14B.

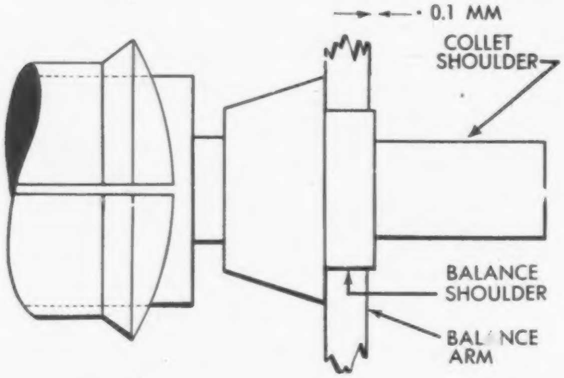
Next, select a sharp, pointed graver and turn a back taper on the cone. Study figure 8-15A. Note the direction of this cut. CAUTION: To prevent breakage of the fine point on the graver, use much care in making this cut. Continue your turning by putting a bevel on the upper end of the collet shoulder, as shown in figure 8-15B.

Now use an iron slip (fig. 8-16A) charged with oilstone powder to grind the hub and the collet shoulder, in the manner illustrated in figure 8-16B. The purpose of this grinding is to remove turning marks and to get the correct diameter. Clean thoroughly with pithwood. CAUTION: You must have everything ABSOLUTELY CLEAN before you start to polish the staff.



91.291X

Figure 8-9.—Marking the length of the balance shoulder.


0.1 MM
COLLET SHOULDER
BALANCE SHOULDER
BALANCE ARM

91.292X
Figure 8-10.—Turning the collet shoulder.

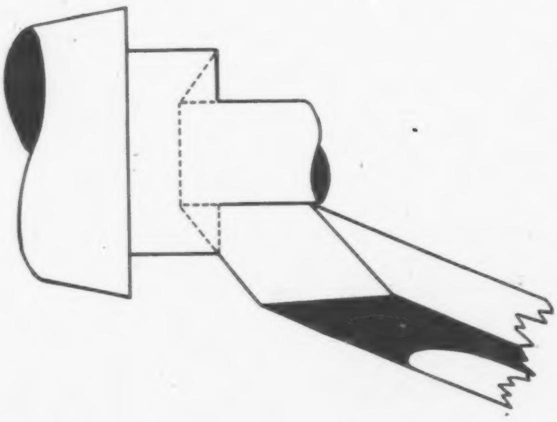
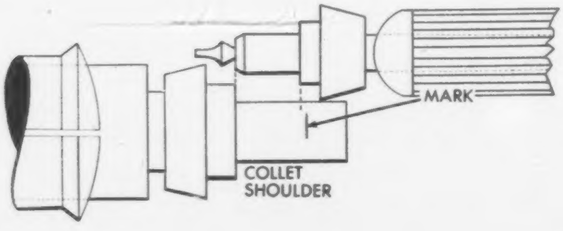
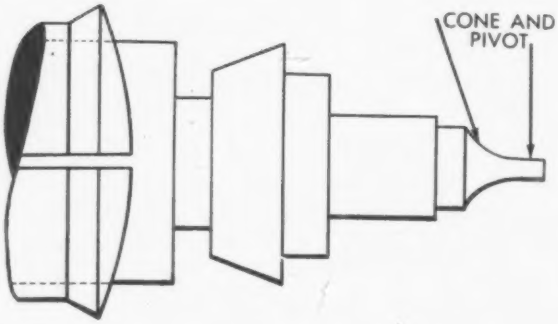


Figure 8-11.—Undercutting a new balance staff for staking. 91.293X


MARK
COLLET SHOULDER

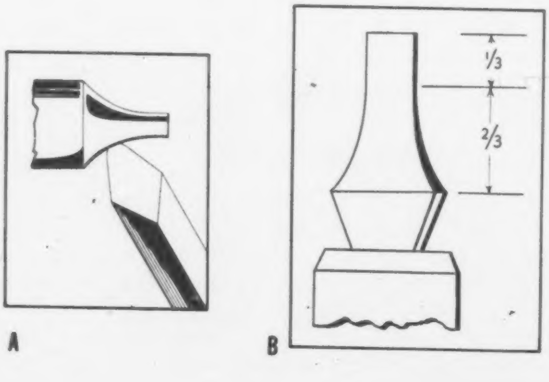
91.294X
Figure 8-12.—Marking the length of the collet shoulder.


CONE AND PIVOT

91.295X
Figure 8-13.—Turning the upper cone and pivot of a new balance staff.

To polish the collet shoulder and hub, put oil and a polishing powder (boron, diamantine, etc.) on a bellmetal slip shaped like the iron slip and grind and polish to correct size. Use the rounded side of the oilstone and bellmetal slip. Frequently test the size of the pivot in the jewel hole to MAKE CERTAIN that you get the correct size.

At this point, reverse the position of the unfinished staff in the lathe and chuck it on the balance shoulder, as shown in figure 8-17. Tighten the chuck enough to prevent the staff from falling out while you run the lathe and



91.296X
Figure 8-14.—Turning the cone on the pivot.

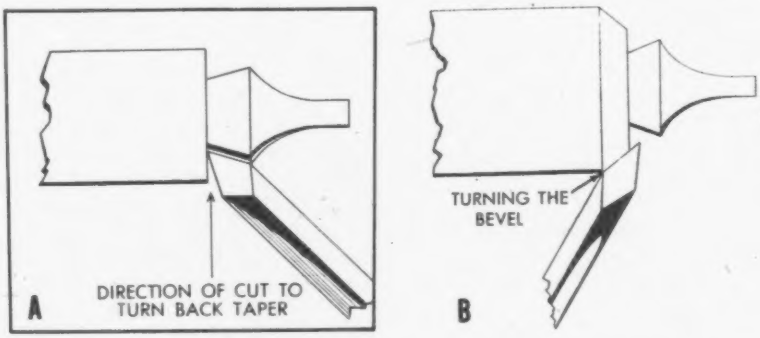

DIRECTION OF CUT TO
TURN BACK TAPER
A
TURNING THE
BEVEL
B

Figure 8-15.—Putting a back taper on the cone, and turning a bevel on the collet shoulder. 91.297X

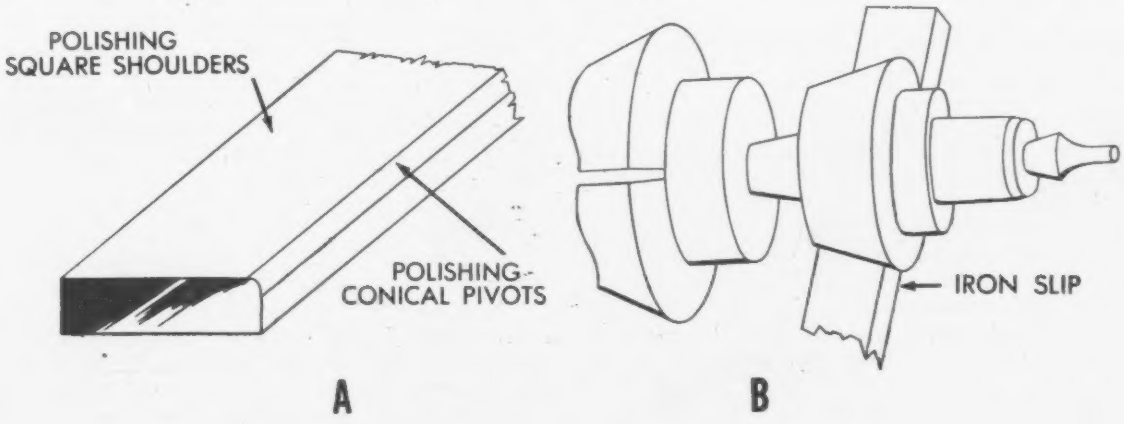

POLISHING
SQUARE SHOULDERS
POLISHING
CONICAL PIVOTS
IRON SLIP
A
B

Figure 8-16.—Grinding the hub and collet shoulder. 91.298X

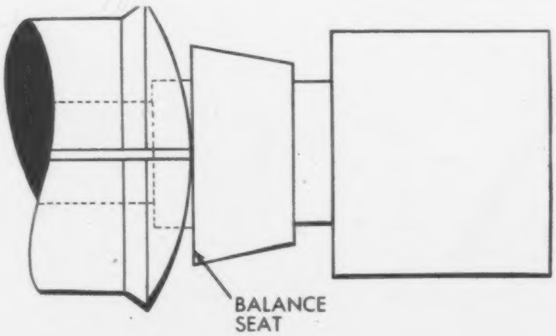
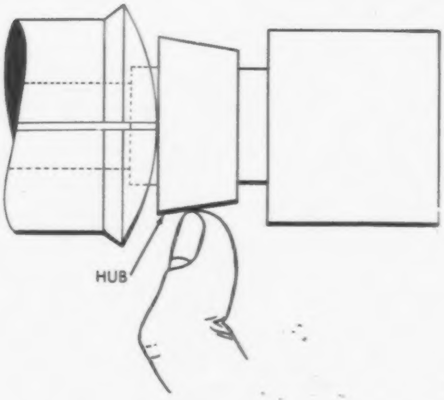

BALANCE
SEAT

Figure 8-17.—Finished end of staff chucked on balance shoulder. 91.299X



91.300X
Figure 8-18.—Truing an unfinished balance staff in a lathe.

test the staff for trueness with your thumb. See figure 8-18. Apply a little pressure with the thumb.

Continue by tightening the chuck and examining the hub for trueness with a DOUBLE-POWERED loupe. Then rest a graver on a T-rest on the underside of the hub and check the space between the hub and graver while the lathe is rotating slowly for trueness of the staff (fig. 8-19A). If the space between the graver and the hub of the balance staff does not vary, you have the staff chucked true.

Using the sample balance staff as a gage, check the length of the hub of the new staff and make corrections, if necessary. Study figure 8-19B, with the sample staff in a pin vise.

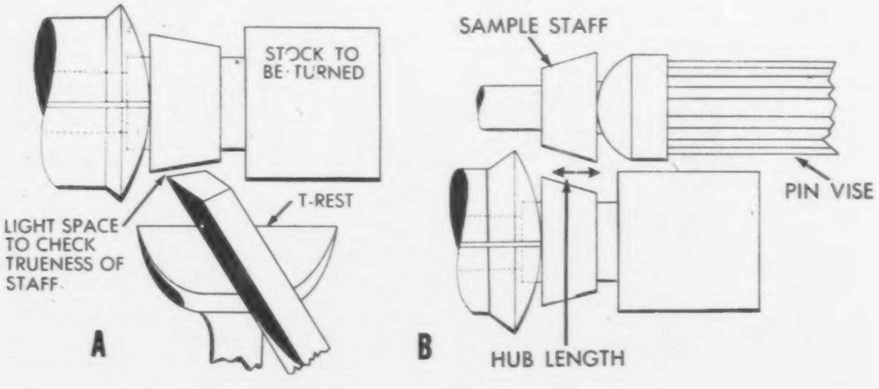
Next, turn the roller shoulder with a sharp taper until you have its diameter .02 mm thicker than the roller shoulder of the sample staff (fig. 8-20A). Then undercut the roller seat very slightly, as shown in figure 8-20B. After you finish the grinding and polishing, the roller shoulder must still remain a square shoulder.

Now turn the lower cone and pivot, using the sample staff as a gage. See figure 8-21. Then select a sharp, pointed graver and turn a back taper on the cone (fig. 8-22A). Many staffs, however, are made without this back taper, as shown in figure 8-22B.

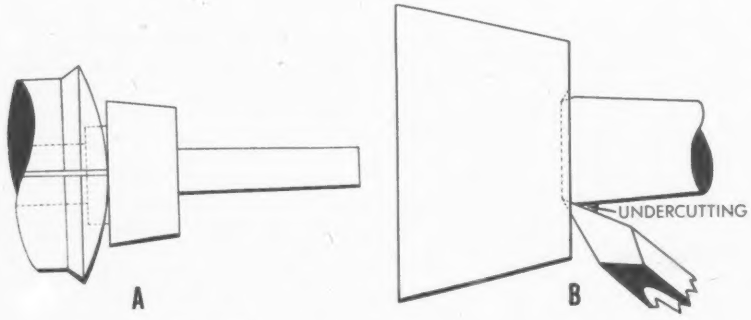
Your last step in turning a balance staff by Method No. 1 is to grind the lower part smooth with an iron slip charged with oilstone powder and then to polish it with polishing powder (diamantine). After you stake the balance wheel to the staff, burnish the ends and sides of the pivots.

Method No. 2

The second method for turning a watch balance staff is explained step by step in this section. Some watch repairmen prefer this method for turning the lower portion of a balance staff. One advantage this method does have is that it ENSURES PERFECT CENTERING of the pivots

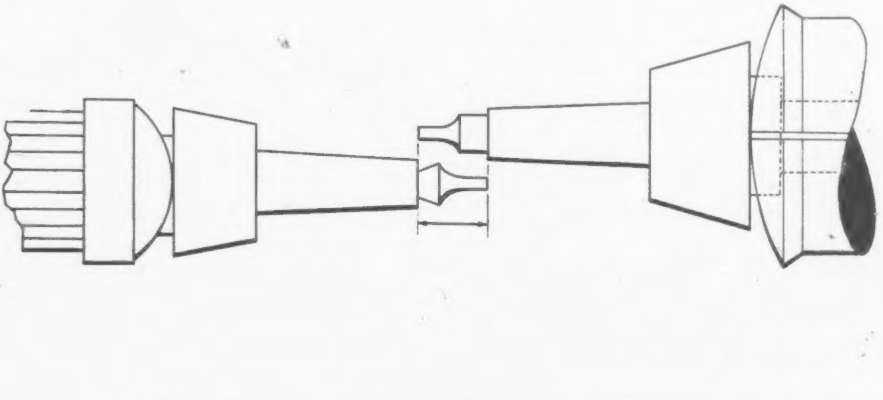


91.301X
Figure 8-19.—Testing the trueness of a chucked balance staff, and checking the length of the new hub.


UNDERCUTTING
A
B

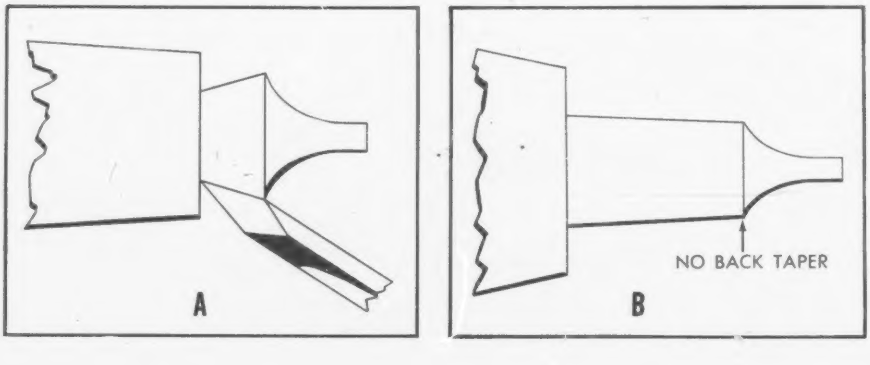
91.302X

Figure 8-20. — Turning the roller shoulder of a new balance staff.



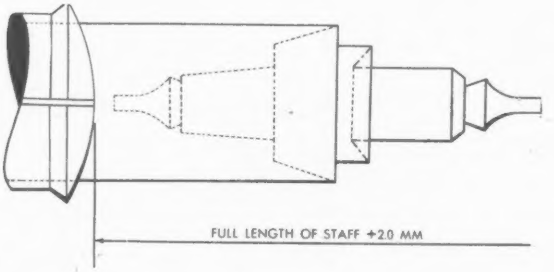
91.303X

Figure 8-21. — Turning the lower cone and pivot.


NO BACK TAPER
A
B

91.304X

Figure 8-22. — Cutting a back taper on the lower cone; cone without back taper.



91.305X
Figure 8-23.—Steel wire chucked in a lathe for turning the balance staff by another method.

of the new staff, as you will see by studying the procedure, as follows:

1. Chuck the steel wire selected for the balance staff in the lathe in the manner shown in figure 8-23. Note that the amount of the wire you should have extending out from the chuck is equal to the FULL LENGTH of the balance staff PLUS about 2 mm extra.

2. Follow the procedure explained in Method No. 1 for turning the top of the balance staff.

3. Rough out the lower part of the staff. CAUTION: It must be long enough to include the lower pivot. See figure 8-24.

4. Insert a brass chuck in the lathe and turn the end flat (fig. 8-25A). Then cut a reservoir in the piece of brass, starting at the point indicated in figure 8-25A and finishing as shown in figure 8-25B. Note the T-rest on which you should rest the graver while you make the reservoir. The reservoir must be deep enough to engulf the entire upper portion of the balance staff; and the V point must be the DEAD CENTER point in the brass. Study figure 8-26.

5. Warm the end of the brass chuck with an alcohol lamp and pack your reservoir with shellac. Then apply more heat to soften the shellac.

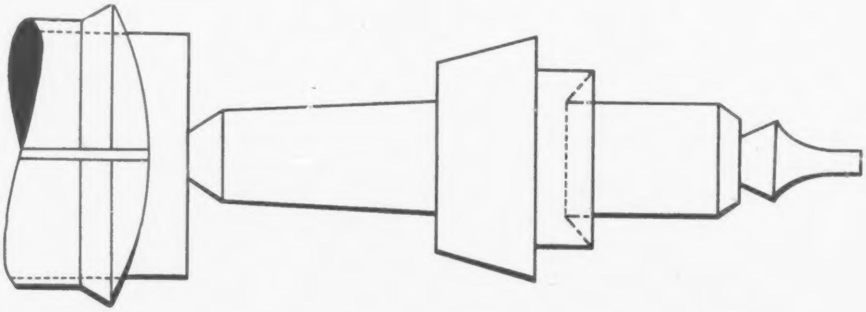
6. Insert the finished portion of the balance staff in the soft shellac and apply enough pressure with a finger (with the lathe running) to push the pivot to the bottom of the V of the reservoir (fig. 8-27). Then keep the lathe rotating until the shellac hardens.

7. To true the staff, apply a little heat (enough to enable you to move the staff in the shellac). Then rest a piece of pegwood on the underside of the staff and true the staff with the lathe running. Barely touch the roller seat with the pegwood during the truing operation. Check the staff for trueness by the method previously described in this chapter. Study figure 8-28.

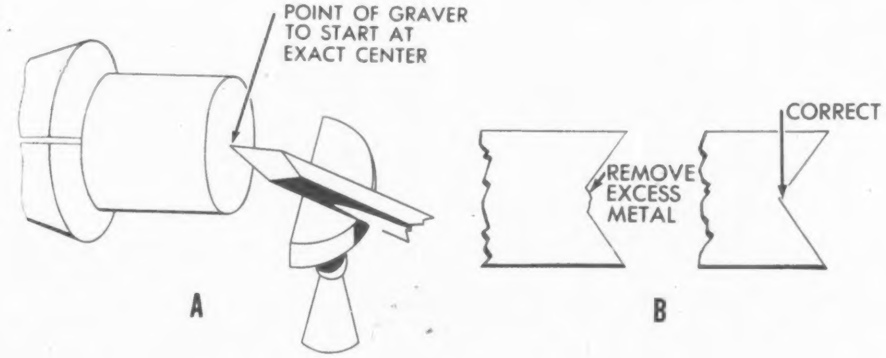
8. Use the old staff as a gage and reduce the lower part of the balance staff to the correct length, as illustrated in figure 8-29. Then turn, grind, and polish the lower staff just as you did when you made a staff by Method No. 1 (in the discussion).

9. To remove the completed balance staff from the shellac, heat the brass until the shellac is soft and pull the staff out.

10. Boil the balance staff in alcohol to remove the shellac residue which remains on it.

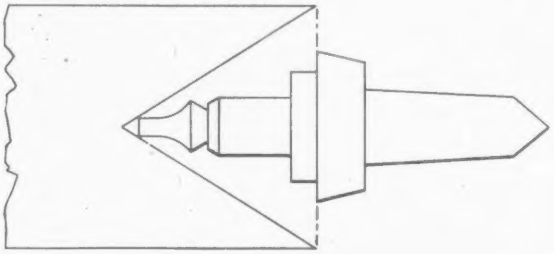


91.306X
Figure 8-24.—Roughing out the lower part of a balance staff.



91.307X

Figure 8-25.—Turning the end of a new balance staff flat and cutting a reservoir in it.



91.308X

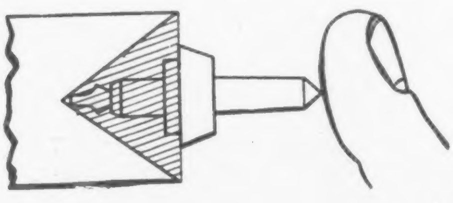
Figure 8-26.—Correctly formed shellac reservoir.

PRESSURE GAGE PINION STAFF

The pinion staff or indicating pointer shaft for a pressure gage may become worn or get bent, and no replacement gage is available. In this case, you would manufacture the staff, using method No. 1 for cutting a balance staff.

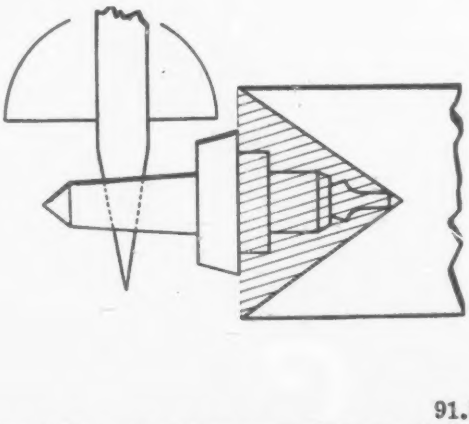
WATCH STEM

The tools you need for making a watch stem are illustrated in figure 8-30. If another watch stem is available, use it as a sample while



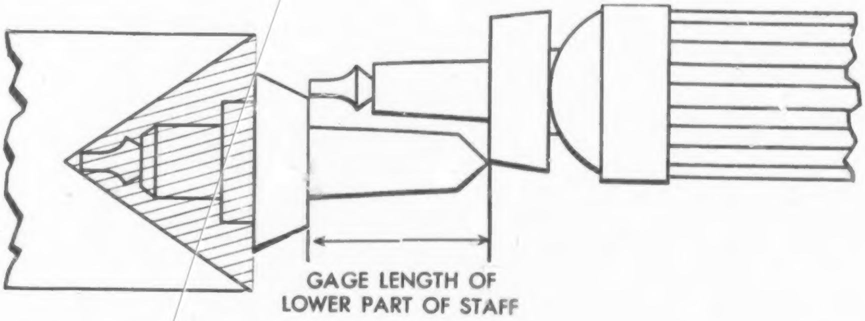
91.309X

Figure 8-27.—Inserting the finished portion of a new balance staff in soft shellac.



91.310X

Figure 8-28.—Checking a new balance staff in a shellac reservoir for trueness.

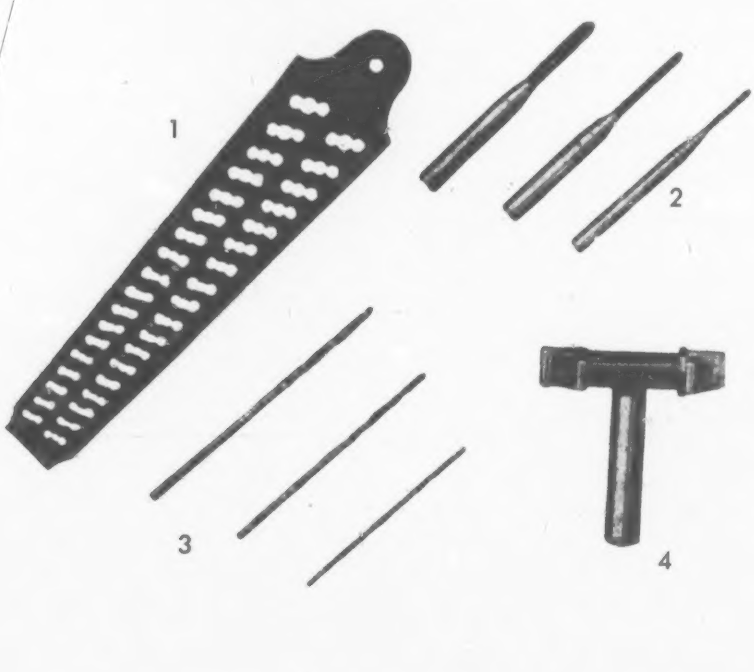


91.311X

Figure 8-29.—Reducing the lower part of a new balance staff to correct length.

manufacturing your new one. The procedure for making a stem follows.

Select a piece of soft steel wire whose diameter is slightly greater than the greatest diameter of the sample watch stem (or dimensions on your sketch). Then chuck the steel wire in a lathe, with enough of it protruding for the pilot, winding pinion, and clutch wheel shoulders. See figure 8-31. Next, place the sample stem parallel with the blank and make a mark on the steel wire with a graver to indicate the length to make the pilot seat of the new stem. Turn the pilot .02 mm larger in diameter than



91.312X

Figure 8-30.—Tools required for making a watch stem.

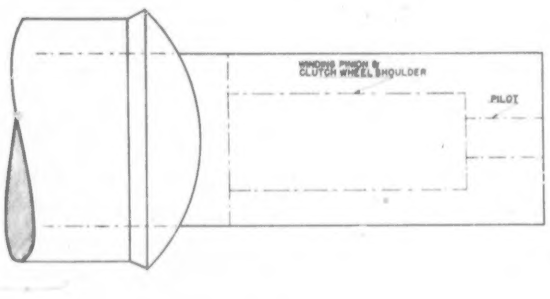
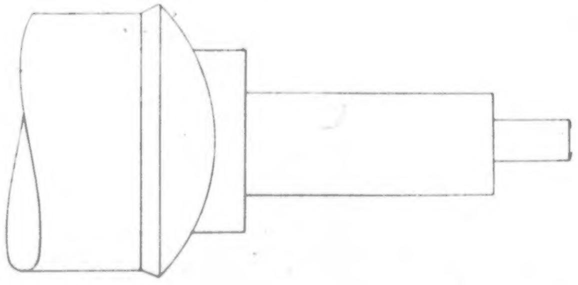


Figure 8-31. — Steel blank chucked in a lathe for turning the pilot, winding pinion, and clutch wheel shoulders. 91.313X



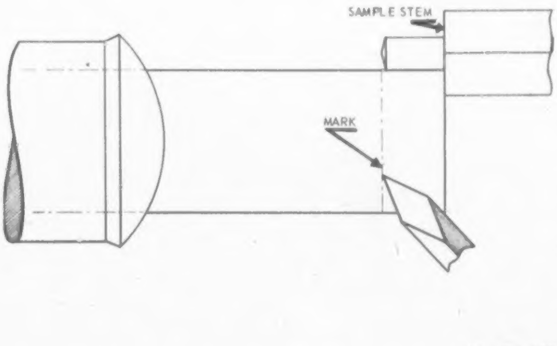
91.315X
Figure 8-33. — Turning the blank for a watch stem protruding from a chuck.

the sample pilot, and then corner undercut the square shoulder (fig. 8-32).

Turn the part of the blank protruding from the chuck .02 mm larger in diameter than the bearing of the sample, as shown in figure 8-33.

Continue the process by placing the sample stem parallel with the blank and marking the seat for the clutch wheel with a graver (fig. 8-34). If the sample is broken at the threads or setting lever slot (usual breaking point), use the section with the clutch wheel shoulder to locate the seat for the clutch wheel. At this mark, turn a slight groove to make a square shoulder for the seat of the clutch wheel, as illustrated in figure 8-35.

Now remove the T-rest and replace it with the filing rest. Adjust this rest as necessary to get the top of the roller level with the blank and approximately 1/2 inch away from the work.



91.314X
Figure 8-32. - Marking the length of a pilot seat with a graver.

Lock the head on the lathe with the index pin (fits in holes of index plate) and you are ready to file the square shoulder for the seat of the clutch wheel. Use a No. 3 file (with safe, non-cutting edge).

Place the file firmly on the roller and take three or four strokes with the safety edge OUT OF CONTACT with the square shoulder (fig. 8-36). Other strokes may then be made with the safety edge against this shoulder without fear of the file's going past it.

Take two more strokes with the file and then turn the headstock 1/2 turn (180°). Lock the headstock with the index pin and repeat the above filing procedure on this side of the blank. Use a micrometer at this point to check the diameter of the flat sides with the square of the sample. Then continue filing the same amount on each side until the diameter of the flat sides is equal to the square of the sample. Study figure 8-37.

Next, turn the headstock 1/4 turn (90°) and file the third side of the square, using the same procedure as for the first side, as indicated in figure 8-38.

Turn the headstock 1/2 turn (180 degrees) and file the fourth side. Use precaution in checking the diameter. When the square is completed it should look like the one on the stem shown in figure 8-39.

Put the unfinished stem parallel with the sample stem on the bench and mark the unfinished stem to indicate the threaded portion, as illustrated in figure 8-40, and then cut off the excess portion of the metal (left vertical mark in figure 8-40). In case the sample stem is broken at the setting lever slot, use the threaded section to mark the length of the

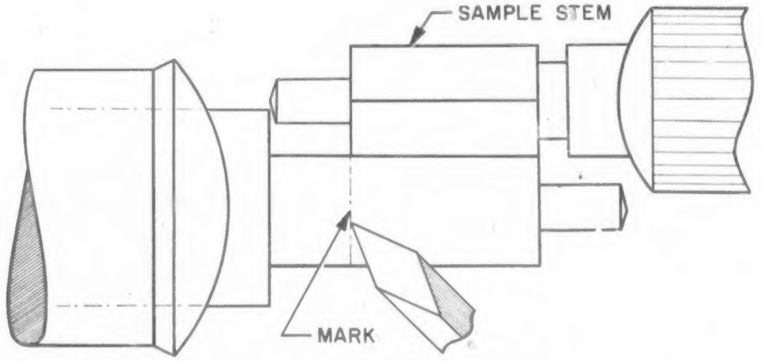

SAMPLE STEM
MARK

Figure 8-34.—Marking the seat for the clutch wheel. 91.316X

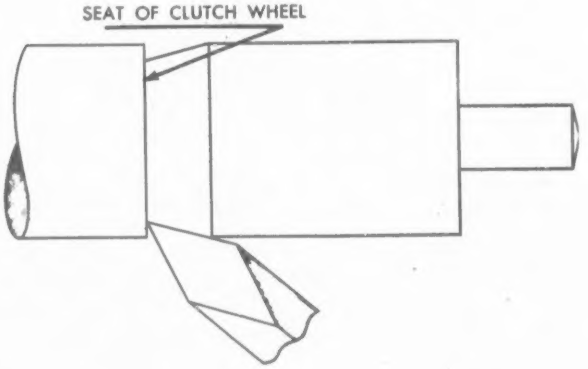

SEAT OF CLUTCH WHEEL

Figure 8-35.—Turning a square shoulder for the seat of a clutch wheel. 91.317X

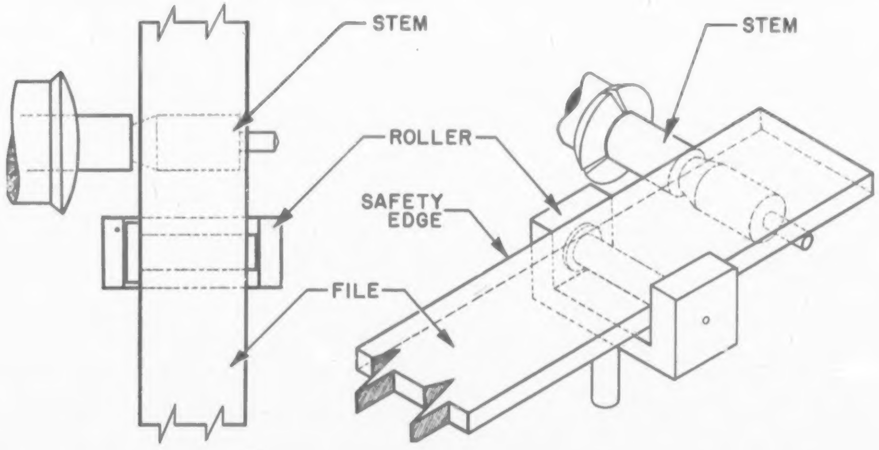
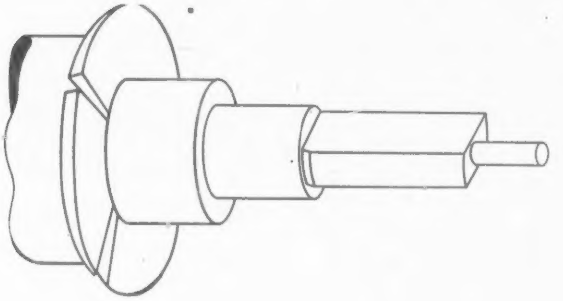
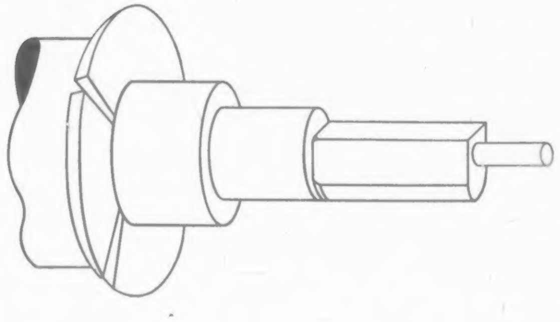

STEM
ROLLER
SAFETY EDGE
FILE
STEM

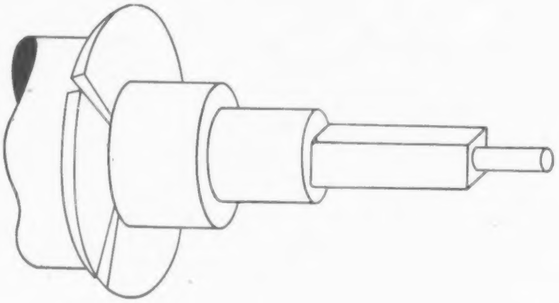
Figure 8-36.—First step in putting a square on the shoulder. 91.318X



91.319X
Figure 8-37. — Second step in forming the square on the shoulder.



91.320X
Figure 8-38. — Filing the third side of the shoulder.



91.321X
Figure 8-39. — The completed square.

threaded portion of your new stem. If the threaded portion of the sample is broken, be sure to make the threaded portion of your stem long enough to allow for the crown.

Use the right type of chuck to hold the bearing of the stem in the lathe and turn the shoulder for the threads. See figure 8-41. To determine the diameter of your new thread shoulder, make it small enough to fit in the screwplate hole which is two holes larger than the one you will use to cut the threads. CAUTION: In some screwplates, you must use just one hole larger than the one you will use for cutting the threads. Experience with your own screwplate will solve the problem of determining which hole to use for turning the thread shoulder. After you turn the shoulder for the threads, it looks like the one illustrated in figure 8-42.

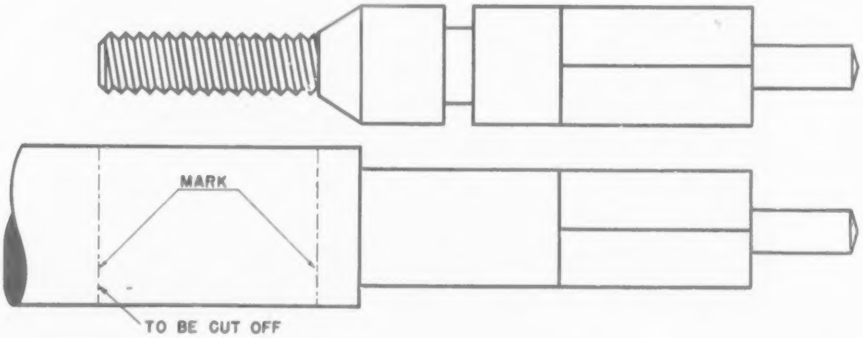


Figure 8-40. — Marking the part of the new watch stem to be cut off. 91.322X

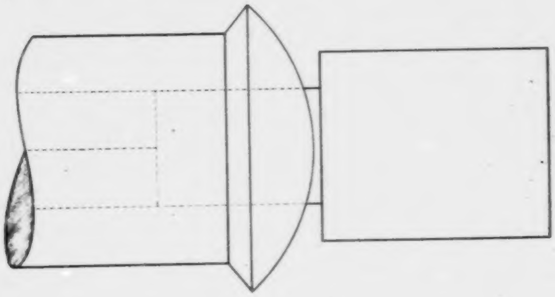


Figure 8-41.—Turning the shoulder for the threads. 91.323X

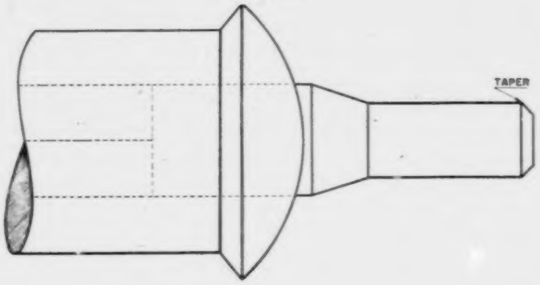
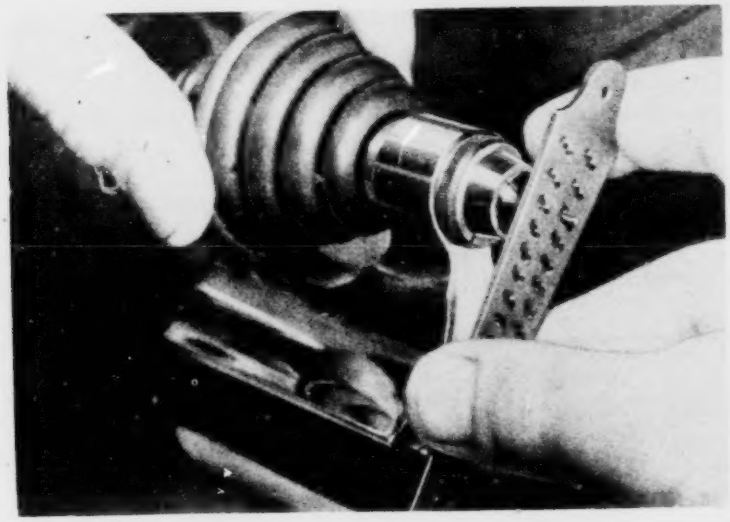


Figure 8-42.—Stem shoulder ready for cutting threads. 91.324X

To enable the screwplate to start cutting threads, turn a small taper on the end of the shoulder (fig. 8-42). Then continue with the cutting of the threads as shown in figure 8-43. Turn the screwplate with the right hand and the headstock of the lathe with the other hand. Use sufficient oil to make cutting easier and to prevent overheating of the metal. Move the headstock in one direction and the screwplate in the other direction (backward and forward) until you get the threads cut the required length. Stop to add more oil, as necessary. CAUTION: If you try to cut the threads too rapidly, you may twist the shoulder off.

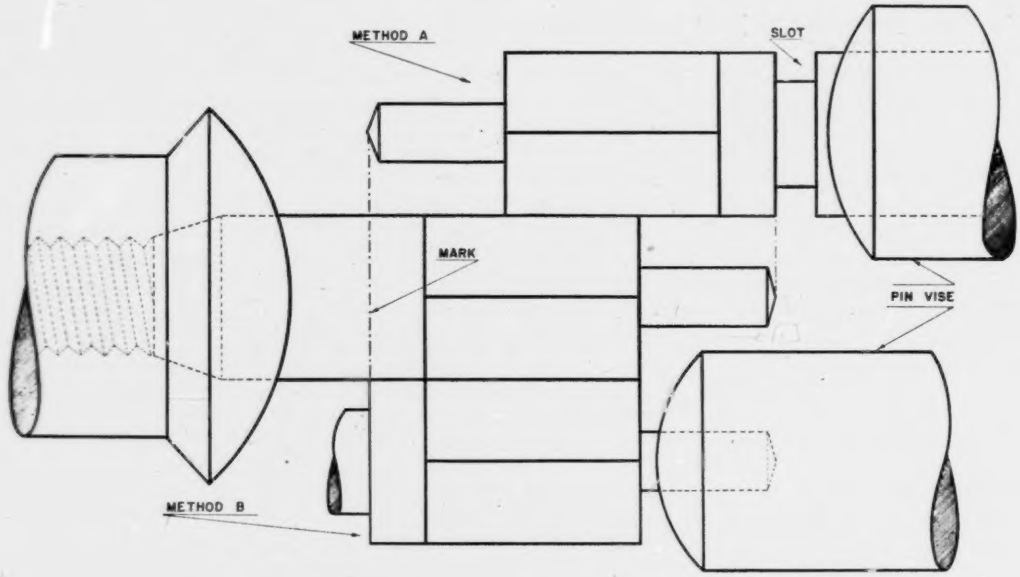
Before you turn the slot for the setting lever, harden and temper the unfinished stem.

Now chuck the stem in the lathe and place the sample stem parallel with the unfinished stem (fig. 8-44A). Then use a graver to mark the slot for the setting lever. (If the sample



91.325X

Figure 8-43.—Cutting threads on the shoulder.



91.326X

Figure 8-44.—Marking the slot for the setting lever.

stem is broken at the setting lever slot, hold the sample stem parallel with the unfinished stem in the manner illustrated in figure 8-44B).

With a special kind of graver (fig. 8-45A), turn the slot for the setting lever, same dimensions as the slot in the sample. Figure 8-45B shows the completed setting lever slot.

To remove all traces of turning marks, grind the bearing and the pilot of the stem with a triangle slip charged with oilstone powder and

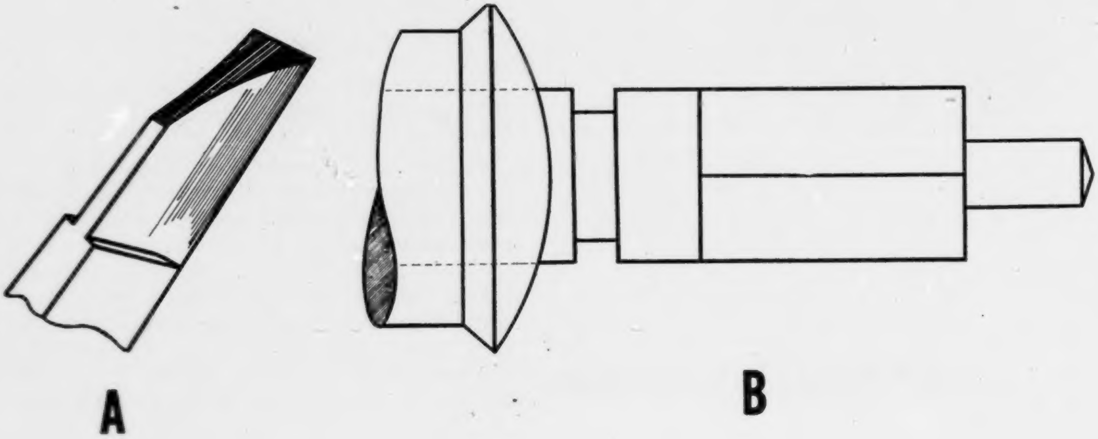


Figure 8-45.—Turning the slot for the setting lever.

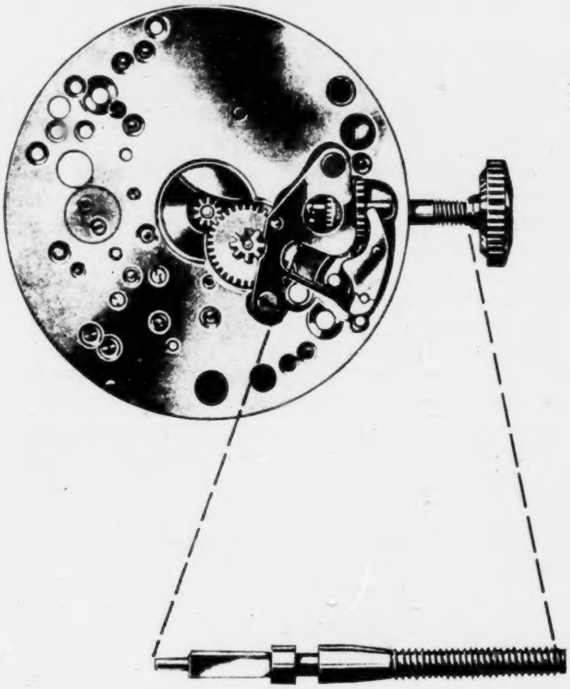
91.327X

oil. Then clean the stem thoroughly in preparation for polishing.

Chuck one female center in the headstock and another female center in the tailstock of the lathe. Fit the stem between these centers and check it for freedom of movement. It must move freely in order to find its own level when you apply a little pressure to the polishing slips. Using the same procedure you followed for grinding and polishing the bearing and pilot, grind and polish the square of the stem. This is the last step in making a watch stem to match a sample stem. Your new item should look like the one shown in figure 8-46.

MAINSPRING BARREL ARBOR

Although this section deals primarily with the procedures for making a mainspring barrel arbor, you will learn by studying it how to make most any type of arbor for pressure gages, watches, and clocks. As explained previously, whenever possible, use another arbor as a sample when you make a new one. Even though worn or broken, you can still use it as a guide in obtaining the correct contour for your new part.



91.328X

Figure 8-46. — The completed watch stem.

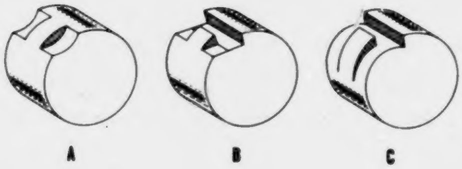
Select for your new barrel arbor a steel rod slightly larger in diameter and longer than the sample arbor, or in accordance with a sketch for the new arbor. NOTE: It is ALWAYS BEST to prepare a sketch for most new parts you must manufacture; and information on the sketch (dimensions and specifications) is invaluable for making some instrument parts.

Unless it is too small to hold the rod in the lathe, use an ordinary split chuck; if necessary, use a larger screw chuck. You can adjust the screws of this chuck one at a time to center the rod. Then use a graver (with T-rest) to cut the rod to correct length and to turn one end of the arbor almost to the finished size. Then reverse the rod in the lathe, centered in a split chuck, and turn the other end almost to size.

To make the square of the new arbor, tighten the part in the lathe and lock the headstock with the index pin in one of the quarter holes on its pulley. Then position the roller rest level with the top of the arbor. Hold the roller rest firmly and use a fine, flat file in the horizontal position while you file one side. Turn the headstock 180° and lock it, and file 10 to 12 strokes on the side opposite the first one you filed. Turn the headstock 90° and file the third side; and then turn it 180° and file the fourth side. Check the dimensions frequently as you file to make certain you are fashioning the pivot correctly and making it square.

Now check the ratchet wheel on the arbor. If necessary, reduce the size of the square in order to get a good fit. If the ratchet wheel is the type which is held in position by a screw, turn away all the square section of the arbor not required for the ratchet wheel and tap the remaining part for the screw.

Next, make the hook on the arbor body which holds the mainspring. Tighten the arbor in the split chuck and lock the head again with the index pin. With a fine jeweler's file, cut a slot across the arbor body. Then remove the arbor from the chuck and cut two broad slots perpendicular to the first slot (fig. 8-47B). Continue filing with the flat side and the edge of a file until you fashion the hook in the manner shown in figure 8-47B and C. The depth of the slot between the hook and the body of the arbor should be the same



91.329X
Figure 8-47.—Forming the hook on a new mainspring arbor.

as that of your sample hook, and the face (where the spring hooks) of the catch should be square with the bottom of the slot, or cut to a slight angle toward the out side of the arbor (to hold the spring better). The depth of the slot (height of the face of the hook) should be equal to the thickness of the mainspring.

To harden your new arbor, heat it to a cherry red color and then plunge it into cool oil; to temper the arbor, heat it to a pale straw color and cool it in the atmosphere.

Polish your new arbor all over with a bell-metal slip charged with oilstone powder and oil. Polish both pivots with an iron slip and diamantine.

When you finish polishing the new arbor, mount it in a split chuck and turn the arbor body enough with a sharp graver to get the measurement of the shoulder which turns inside the barrel slightly less than the full diameter of the body. Give the new part a slight taper, to allow the pivots to receive oil. Reverse the arbor in the chuck and finish the other end in the same way.

INSTRUMENT BUSHINGS

Because Navy watches have jeweled bearing surfaces for most of their wheel arbors and balance staff pivots, you will seldom (if ever) be required to insert bushings in watch plates; but you will have to put new bushings in clocks and gages.

If you find a non-jeweled clock plate bearing scored or oval-shaped, plug it and also the two adjacent bearings. With dividers centered on the adjacent bearings, inscribe arcs on the plate. Record the radius of each arc, so that you can check the new bearing center later. Use a cutting broach to shape and smoothen the damaged bushing hole. Be careful about retaining the original center. This procedure is followed for both clock and gage plates.

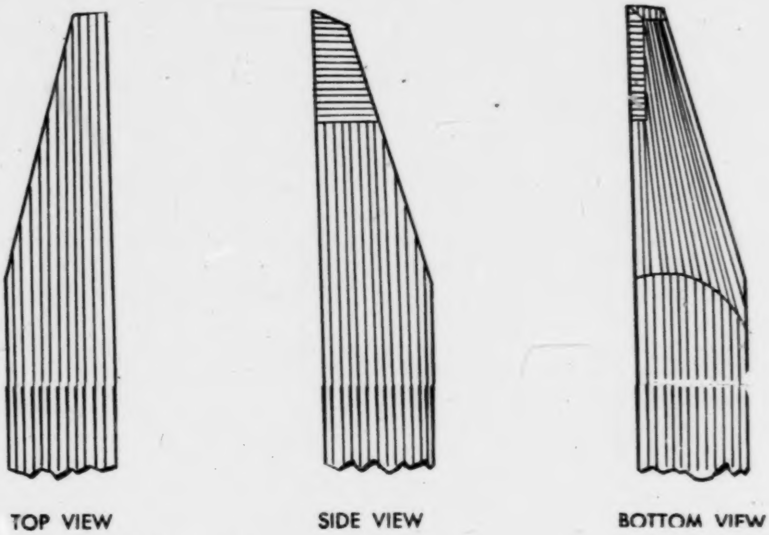
Drilled brass bushing rods can be procured in assorted lengths from 2 1/2 inches up, and from 1/16 to 1/8 inch in diameter. The hole in the rod you select for replacing a bushing should be slightly smaller in diameter than the pivot which is to fit in it. The length of the rod selected for the bushing should be four times as long as the finished plate hole.

After you select a bushing rod of the correct size and length for a plate hole, proceed as follows to make the bushing:

1. Turn the bushing rod on an arbor until it has the same taper as that of the broach.
2. Enlarge and smoothen the plate hole until it has exactly the same taper as the bushing rod.
3. Pass the rod through the smoothened plate hole and mark it at two points: (1) a small distance above the plate hole, and (2) a small distance below the plate hole.
4. Turn off the extra amount of rod at each end.
5. Undercut the top end of the rod to enable you more easily to form a rivet, and chamfer the upper side of the hole to receive it.
6. Next, put the plate and rod on a staking tool (underside of plate up) and fasten the rod tightly in the plate with a flat-end seating punch. Repeat this operation on the other side of the plate, but use a round-end spreading punch. Use light taps with a hammer to rivet the chamfered side.
7. If the new bushing is too long, cut enough off the tapered end to make the length correct. Then polish the edges of the bushing with an India stone slip.
8. Verify the center of the new bushing by checking it with the intersection of the two arcs you previously described. NOTE: The center of the new bearing must coincide with the original center of the hole.
9. Open the new bushing to the correct size with a tapered broach, and finish it off with a round broach to polish the hole.

JEWEL MOUNTINGS

Watch jewels are inserted directly into the plates in many watches; but in a large number of other watches the jewels are first mounted in brass or gold settings, and then both settings and jewels are fitted friction-tight in the plate.



61.79X

Figure 8-48.—Special jewel graver with inlaid cutting edge.

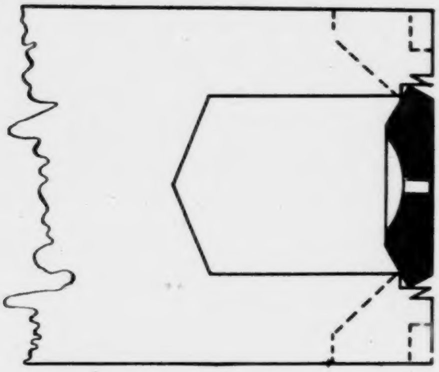


Figure 8-49.—Jewel inserted in a mounting against the seat. 91.330X

A jewel mounted in this manner is called a BEZEL jewel. On occasions, however, you will need a jewel mounting which cannot be replaced from stock and your only alternative is reproduction.

The procedure for making a jewel mounting is described in the next paragraphs, as follows:

1. Chuck a piece of 4 mm brass wire in a lathe and square off the face with a graver. The turn a small center in the new face.

2. With a drill slightly smaller in diameter than the jewel which will fit in the mounting, drill a hole approximately 5 mm deep in the brass wire. Select a jewel graver with an extremely hard, inlaid cutting edge (fig. 8-48) and enlarge the hole slightly. Then true the hole.

3. Next, turn the jewel seat (fig. 8-49) to a depth a fraction more than the width of the jewel for which it is intended. When you insert the jewel, it should lie a little below the face of the mounting.

4. Now select a long, pointed graver and cut a groove close to the opening of the surface of the mounting.

5. Then check the dotted lines in figure 7-49 to learn how to turn the setting so that it fits the watch plate.

6. Continue the process by moistening the jewel with oil (to hold it in place) and by inserting it in the mounting. In order to set the jewel securely, rest a jewel burnisher on the T-rest and spin the metal adjoining the groove onto the jewel.

7. Before you cut off the unused part of the brass wire, check for endshake. If the amount of endshake is satisfactory, cut the wire off, turn it to the proper thickness, and strip it out with a sapphire jewel stripper or a highly polished graver. Polish the face by sliding it

over an agate polishing stone or a similar finishing agent. The mounted jewel is then ready for insertion in the plate. When you do this, adjust for endshake by raising or lowering the jewel in the pillar plate.

When you replace a balance hole jewel in its old setting, allow a clearance of .01 mm to .02 mm from the bottom of the hole to the outer edge of the setting — to ensure proper capillary action of the oil when the endstone is in position against the pivot. If your mounting appears to fit loose, spread it by tapping it on a staking stump with an inside taper punch.

If you should be required to remake a backplate for a tachometer, acquire a sheet of stainless steel of the correct thickness and make a layout using a template. See chapter 8, Blueprint Reading and Sketching, NavPers 10077-C, for sheetmetal layout drawings. Then cut and drill the plate to the correct specifications.

CHAPTER 9

ELECTRIC TYPEWRITERS

This chapter presents the IBM Selectric Typewriter, with cleaning instructions, operation and procedure for adjustments. As an Instrumentman First Class, you must be able to analyze casualties, disassemble, clean, inspect, replace faulty parts, reassemble and adjust Selectric Typewriters.

Space in this text does not allow a detailed discussion of all makes and models. The standard electric models are discussed in IM 3 & 2, NavPers 10193-C, and further details of the standard electric models can be found in appropriate manufacturers' handbooks and instruction manuals, as with the IBM Selectric.

THE IBM SELECTRIC TYPEWRITER

ONE OF THE earlier versions of the typewriter was based upon a principle that now has been used to make the first major innovation in the design of typewriters. The principle used by W. A. Burt in 1829 is one that you should be familiar with if you have ever seen a toy typewriter. The type that Mr. Burt used for his typewriter was regular printer's type mounted on a semicircular device. The idea was to rotate the device until the desired letter was in the proper position and then press it down against the paper to print. Mr. Burt invented his machine to cut down on the time he was spending on his paperwork. After spending considerable time and effort on perfecting his typegrapher, Mr. Burt found that the machine looked good, printed a nice line, and had only one defect. The one drawback was that it was "slightly" slower than longhand.

The Selectric typewriter; which is IBM's latest model, is also based upon the principle of a rotating typing element. The type element is round like a ball and has the alphabet on it in both uppercase and lowercase. In addition, this type head, as it is called, has numerals from 0 to 9 and the necessary punctuation to prepare typewritten material. The type head can be rotated and tilted until the selected character is in the proper position and then the type head strikes a ribbon which makes an impression on paper. One of the main differences between this machine and Mr. Burt's 1829 model is that this machine, operated by a magnetic tape control unit, can achieve a speed of 190 words per minute which is "slightly" faster than longhand.

Most of the features found in this machine are unique. However, you will find some similarity to some of the equipment we have previously discussed. The use of this machine is on the increase in the Navy. It is used as the printout unit for many of the electronic data processing units being installed in the Navy and in industry.

So, let's look at some of the details of the components that make up this unique electric typewriter.

MOTOR AND DRIVE

MOTOR AND ELECTRICAL PRINCIPLES.—The motor now used in the Series 72 Selectric Typewriter is a shaded pole, induction type motor that requires 115 volts, 60 cycles AC. It is rated at 1/40 hp. The motor, illustrated in figure 9-1A is mounted at the left rear corner of the machine with the pulley toward the right. It is attached to an adjustable bracket at each end by ring-shaped spring retainers that encircle the rubber motor mounts.

You should seldom, if ever, have to disassemble the motor; if you do, however, be careful not to invert either end bell when replacing it. If the end bells are inverted, the oil hole in the left end bell and the notch in the bearing will be on the bottom.

The starting torque for the motor is provided by the shaded pole principle. No capacitor is required as in motors used with previous models. The motor has an internal circuit breaker to prevent damage to the field coil in the event

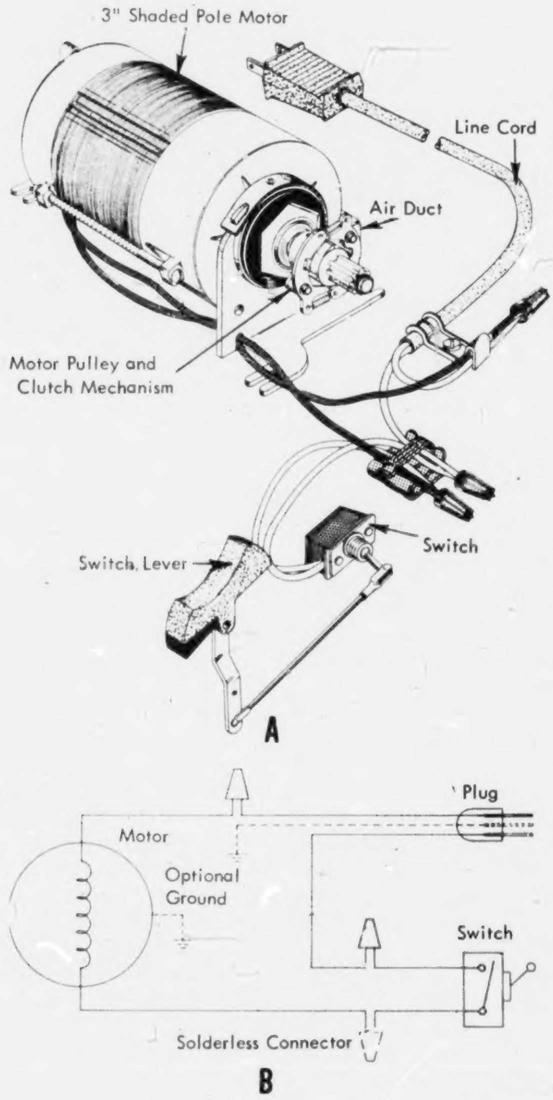


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Figure 9-1.—Motor unit.

the switch is left on with the machine stalled. The circuit opens only if the motor is allowed to remain stalled for a long period of time; therefore, there is no danger of an open circuit during normal operation. The motor stalls only in rare cases where a maladjustment or parts breakage causes the machine to lock. After a stalled motor has regained normal temperature, the circuit breaker again closes the circuit. The circuit breaker continues to open and close as long as the motor is stalled and the switch is left on.

Because of its design, the shaded pole motor tends to run at a higher temperature than other typewriter motors. Care should be taken in handling the motor to prevent being burned. In order to prevent overheating, a cooling system is incorporated in the design of the motor. The Instrumentman must know how and where to ground the IBM Selectric typewriter. A single ground connection will not provide complete protection to the operation. You must be able to point out to the electrician how the motor is to be grounded.

In two-wire, ungrounded systems, the motor is insulated from the powerframe by its rubber motor mounts. In order to convert to a three-wire grounded system (see the schematic in fig. 9-1B), replace the line cord with a three-wire cord and attach the ground lead to the powerframe at the cord clip screw. To complete the grounding, insert a metal clip in the motor mount so as to contact the hexagon end of the motor and the metal ring surrounding the rubber mount.

The switch and switch lever are mounted on the right side of the keyboard. The switch lever operates the electrical switch by means of a short link extending to the rear. It is operated by pressing down on the rear of the lever to turn the machine on and by pressing down on the front to turn the machine off. The switch lever is labeled "ON" and "OFF." When the switch lever is in the ON position, a contrasting color at the front of the switch lever shows just above the case. This calls attention to the fact that the machine is on to minimize chances of leaving the machine running when it is not in use. In addition to operating the typewriter switch, the switch lever also controls the keyboard lockout mechanism. This mechanism is discussed in the keyboard section.

DRIVE MECHANISM.—An eight-toothed motor pulley provides positive drive for the operation of the machine. A positive-drive belt transfers the rotation of the motor pulley to the cycle clutch pulley with a speed reduction of 3 5/8 to 1. To insure the motor will be allowed to start under a heavily loaded condition, a centrifugal clutch has been incorporated in the motor pulley design. The motor is allowed to approach normal operating speed, then the clutch engages to drive the machine. The momentum developed by the rotor causes the machine to start even though several mechanisms may have been tripped with the switch on while the machine was disconnected from the electrical outlet.

The motor pulley operates freely on the end of the rotor shaft and is held in place by a gripping retainer. Ratchet teeth extend radially from the left end of the pulley as shown in figure 9-2. A clutch plate hub assembly is setscrewed to the rotor shaft just to the left of the motor pulley. Pivoted on the plate are two clutch pawls. When the motor is off, the pawls are spring-loaded against stop lugs on the clutch plate. When the motor is turned on the clutch plate turns with the rotor. Centrifugal force causes the clutch pawls to pivot on the studs of the clutch plate so that the tip of one of the pawls engages a tooth of the motor pulley. The pulley is then caused to rotate and drive the machine by means of the cycle clutch pulley. The cycle clutch pulley is mounted to a hub in the center of the powerframe. The hub is supported by a porous bronze bearing and is in continuous rotation with the pulley whenever the motor is running.

Look at figure 9-3 and you will see that on either side of the cycle pulley hub is a shaft extending into and supported by the hub. The shaft to the left of the hub is called the cycle shaft. The cycle shaft is driven by a spring clutch. The clutch is allowed to engage whenever a letter keylever is depressed. The cycle shaft powers the positioning of the type head to the desired character. Its rotation is restricted to 180° each time a character prints. After 180° rotation, the spring clutch is disengaged, allowing the shaft to remain stationary. The cycle clutch is discussed fully in a later section.

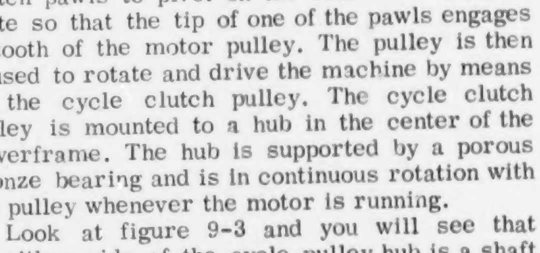

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Figure 9-2.—Motor pulley clutch.

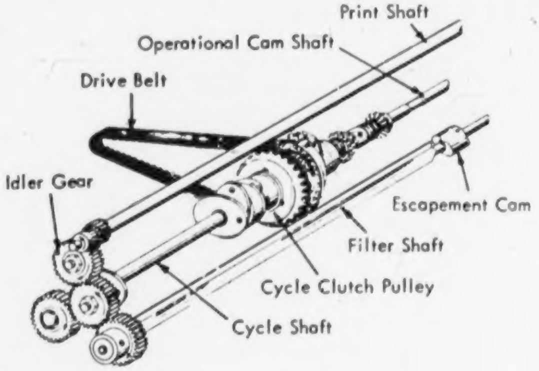

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Figure 9-3.—Drive mechanism.

Through a series of idler gears at the left, two other shafts are driven by the cycle shaft each time it operates. They are the filter shaft and the print shaft. The filter shaft operates the character selection mechanism, the print escapement, the shift interlock, and a spacebar lockout device. The print shaft operates the print mechanism, type aligning mechanism, and ribbon feed and lift mechanisms. The shaft to the right of the cycle clutch pulley hub is the operational cam shaft. All powered functional (nonprint) operations are driven by its rotation. The functions involved are spacebar, backspace, carrier return, indexing, and shift. The shaft also controls the speed of the carrier during a tab operation. Each of the functions is discussed in detail in its own section. Figure 9-4 shows that the operational camshaft is driven by the cycle clutch pulley hub and is in continuous rotation whenever the motor is running. The right end of the shaft operates in a self-aligning porous bronze bearing. The left end extends into the cycle clutch pulley hub, where it is supported by a vinyl sleeve. The sleeve provides a snug fit for the shaft in the hub to prevent any noise due to vibration. The driving connection between the cycle clutch pulley hub and the operational shaft is made by two extensions of the hub that fit into cutouts in the left side of the torque limiter hub. The torque limiter hub is held in position at the extreme left end of the shaft by two setscrews. Two nylon inserts fit into the cutouts of the torque limiter hub (around the extension of the cycle clutch pulley hub). The inserts provide a noiseless driving connection between the two hubs.

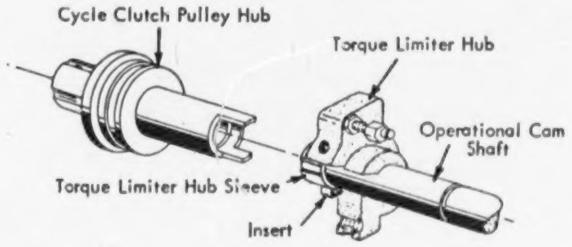

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Figure 9-4. — Operational cam shaft drive connection.

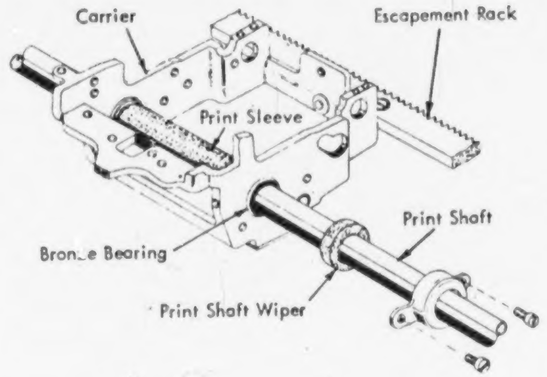

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Figure 9-5. — Front carrier support.

TYPE HEAD

CARRIER ASSEMBLY. — The printing element is a ball-shaped type head containing eighty-eight characters. The type head is supported in front of the paper by a framework called the carrier. The carrier is the box-shaped casting, shown in figure 9-5 that moves laterally just in front of the platen. Its purpose is to transport the type head and other related mechanisms along the writing line. Almost the entire print mechanism is contained within the carrier assembly. In addition, the carrier also supports the ribbon, ribbon feed and lift mechanisms, and a bracket that controls the left and right margins on the paper. At the front of the carrier, a sleeve fits into two bronze bearings in the carrier. The sleeve, called the print sleeve, must rotate within the carrier. It also slides left to right on the print shaft to provide the front support for the carrier. An oil-soaked, felt ring surrounds the print shaft and is enclosed in a retaining cup at each side of the carrier. As the carrier moves, the felt ring, called the print shaft wiper, spreads a light film of oil on the shaft to lubricate the print sleeve. Oil from the print shaft wipers is also absorbed by the bronze bearings in the carrier casting to lubricate the rotation of the print sleeve.

Carrier Support. — The carrier support, is shown in figure 9-6. The upper shoe fits loosely on its eccentric mounting stud and is spring-loaded against the top surface of the escapement rack. This spring load, provided by a leaf spring, removes the play between the lower shoe and the bottom of the escapement rack, thereby eliminating any vertical play at the rear of the carrier during a print operation. The bottom shoe is a nylatron block mounted to a plate that is fastened to the rear of the carrier by the same stud that mounts the upper shoe. A stud, riveted to the plate, anchors the left end of the leaf spring. The right end of the spring presses against the underside of the escapement bracket.

Rocker. — The rocker, shown in figure 9-7 is a pivoting platform located within the rear portion of the carrier. Its purpose is to carry the type head to and from the platen for the print operation. Components involved in the type head positioning and aligning operations are also contained within the rocker. The rocker pivots on the rocker shaft at the rear of the carrier. Two bronze bushings, pressed into the rocker, pivot

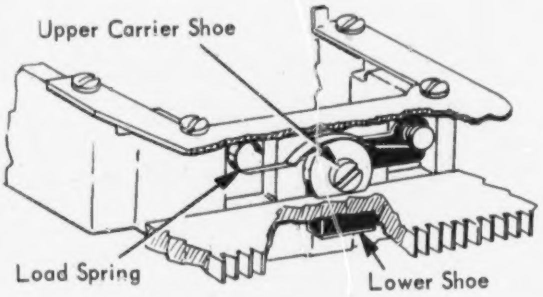

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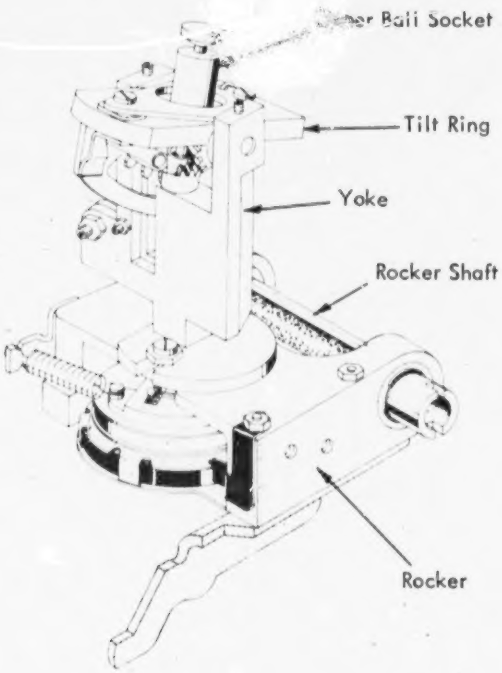
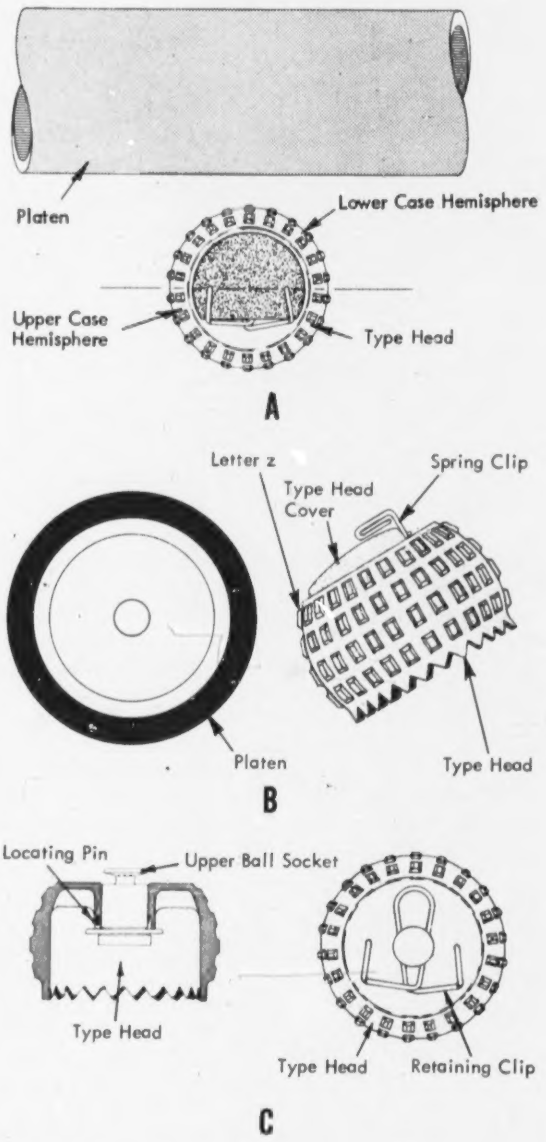
Figure 9-6. — Rear carrier support (new style).


er Ball Socket
Tilt Ring
Yoke
Rocker Shaft
Rocker

91.429
Figure 9-7.—Rocker assembly.

on the shaft and act as the **bearing surface for** the rocker. A C-clip on the right side of the rocker shaft prevents side play in the rocker. A steel thrust washer at the left of the rocker acts as a lateral bearing surface for the rocker. Attached solidly to the top of the rocker platform is the yoke. The yoke has two arms that extend up to provide a pivot mount for the tilt ring. Mounted at the top of the tilt ring is the upper ball socket to which the type head is attached. As the rocker pivots up in front, the yoke moves the tilt ring and the type head toward the platen.

TYPEHEAD.—Assuming machine is in lower case or "home" position, before printing can occur the desired character must be in position to strike the paper. The surface of the type head contains four bands of raised characters with 22 in each band. See figures 9-8A and 9-8B. Each band has eleven lowercase characters in the hemisphere facing toward the platen and eleven uppercase characters in the hemisphere facing away from the platen. At rest, the position of the type head is such that the middle character of the upper band is in position to strike the platen. This is the letter "z." If any character other than the "z" is desired, the head must be tilted up and/or rotated in either direction until the desired character is in the printing position. The arrangement of the characters on the typehead may be found on figure 9-9.


Platen
Lower Case Hemisphere
Upper Case Hemisphere
Type Head
A
Letter z
Type Head Cover
Spring Clip
Platen
Type Head
B
Locating Pin
Upper Ball Socket
Type Head
Type Head
Retaining Clip
C

91.430
Figure 9-8.—Typehead.

UPPER CASE											LOWER CASE											
[	#	&	*	$	Z	@	%	¢	(	)	]	3	7	8	4	z	2	5	6	0	9	T-0
X	U	D	C	L	T	N	E	K	H	B	x	u	b	c	l	t	n	e	k	h	b	T-]
M	V	R	A	0	°	.	"	I	S	W	m	v	r	a	o	!	.	'	i	s	w	T-2
G	F	:	,	?	J	+	P	Q	Y	–	g	f	;	,	/	j	=	p	q	y	–	T-3
R+5	R+4	R+3	R+2	R+1	HOME	R+1	R+2	R+3	R+4	R+5	R+5	R+4	R+3	R+2	R+1	HOME	R+1	R+2	R+3	R+4	R+5	

91.431

Figure 9-9.—Character arrangement on typehead.

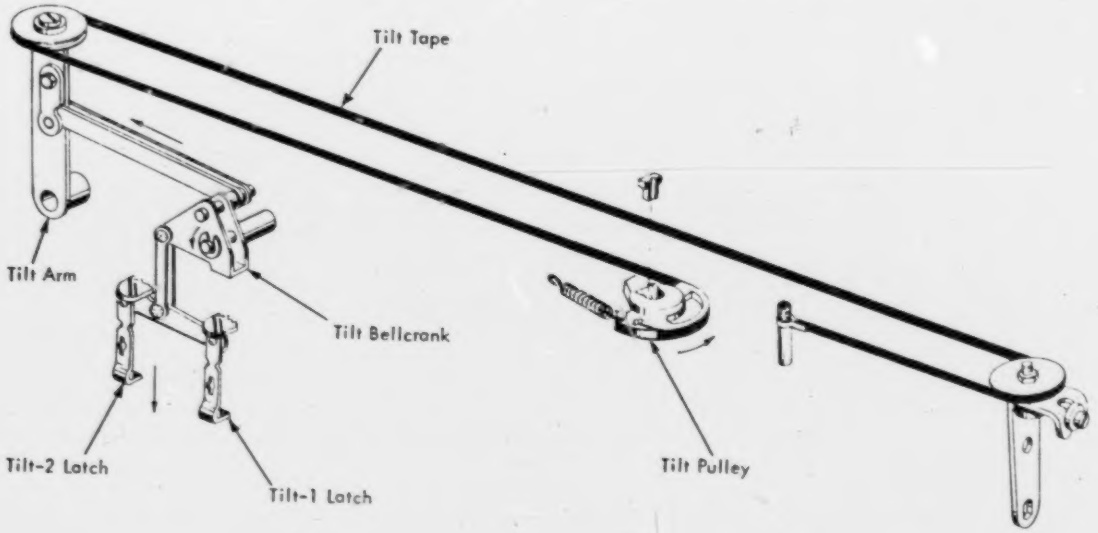
Any lowercase character may be reached by rotating the type head up to five positions in either direction and tilting the head as much as three bands from the rest position. The type head always rotates back to the "z" or "home" position, after a character has been typed. If an uppercase character is desired, the head must be rotated counterclockwise an additional 180° so that the uppercase hemisphere of the type head is toward the platen. The single-unit type head has the advantage over conventional typebars of being relatively inexpensive and easily detached from the print mechanism. This enables the operator to change quickly from one type style to another merely by replacing the type head.

Now consult figures 9-8A, 9-8B, and 9-8C to see how the type head fits around a post, called the upper ball socket, at the top of the rocker assembly and is held in place by a spring clip. The spring clip is located on top of the type head and fits into a groove in the top of the post. A convex disc covers the spring clip except for two ears. The ears of the spring clip are used in removing and installing the head. Press the two ears together and you disengage the spring clip from the groove in the mounting post allowing the head to be slipped up and off. You install the type head by pressing the ears of the spring clip together and slipping the head into place. The type head is keyed to the upper ball socket by a pin so that it can be installed in one position only. The head must be rotated as it is installed until it drops into position on the pin. The spring clip is then released to lock the head in place. When the mechanism is at rest, the type head is always in the "z" position. When the shift mechanism is in the lowercase position, the ears of the head clip are toward the front of the machine.

TILT MECHANISM

The purpose of the tilt mechanism is to raise the rear of the type head to the desired character band so that a character in that band may be brought to the printing point. Refer to figure 9-7 and you will see that the upper ball socket is attached to a platform-like part called the tilt ring. The tilt ring pivots on two pins between yoke arms that fit up inside the hollow of the type head. The yoke assembly is fastened to the rocker to complete the type head mounting. The tilt ring is located at about the center of the type head. As the tilt ring pivots on its pins, it causes the type head to tilt. Because the type head rests with the upper bank in the print position, all tilt operations are upward from the rest position.

As indicated in figure 9-10 we see that a small steel tape encircles the sector pulley and has one end attached to it. When the tape is pulled, it causes counterclockwise rotation of the tilt tube and an accompanying tilt of the type head. When the pull on the tape is relaxed, the sector pulley is restored by its spring, causing the type head to return to the rest position: From the pulley, the tilt tape is guided through the hollow left end of the rocker shaft by a rounded tape guide block attached to the bottom of the rocker. The tilt tape extends to the left around a small tilt pulley back to the right around a



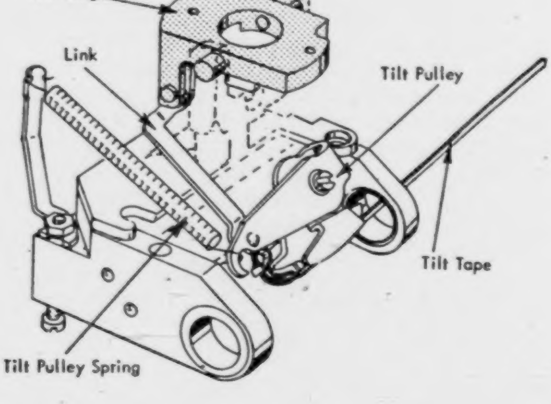
91.432

Figure 9-10. — Tilt tape system.

similar (but stationary) pulley, and is attached to the right side of the carrier. This arrangement allows left to right movement of the carrier without disturbing the position of the type head. When a tilt operation is required, the distance between the two side pulleys is increased by moving the left pulley away from the other. This causes a pull on the tilt tape. The pulley on the right is solidly mounted and is moved for adjustment only. The left pulley is attached to a pivoting arm called the tilt arm. Movement of the arm to the left exerts a pull on the tilt tape, causing the tilt tube to rotate and tilt the type head.

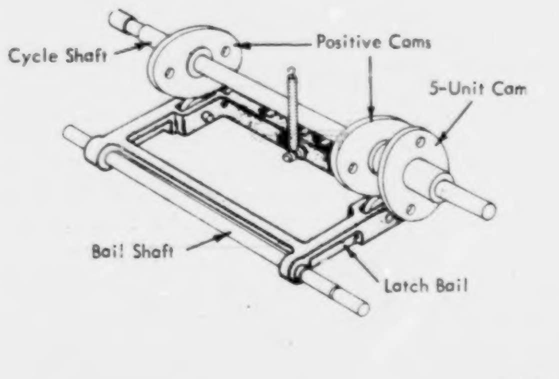
NEW STYLE (GEARLESS TILT). — The gearless tilt mechanism operates basically the same as the early style mechanism. The tilt ring is moved by the operation of the tilt section pulley shown in figure 9-11. A pull on the tape causes this pulley to rotate about its mounting stud; the tilt pulley link transfers the motion to the tilt ring. When the pull on the tape is relaxed, the tilt sector pulley is restored to rest by its extension spring. The tilt pulley link is fastened to the tilt sector pulley by a ball-shouldered rivet to allow the link to pivot in all directions. The other end of the link is fastened to the tilt ring by a pin and C-clip.

LATCH BAIL. — The cycle shaft shown in figure 9-12 has three double-lobed cams on it that power the positioning of the type head. The three cams are separated on the cycle shaft, one on the left and two on the right. The left cam and the middle cam are paired to operate the latch bail located just beneath the cycle shaft.



91.433

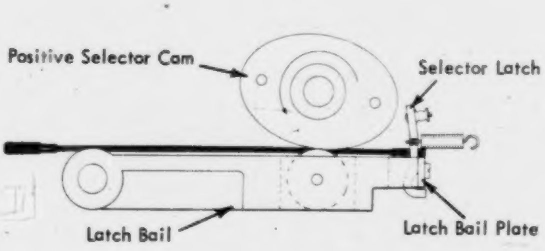
Figure 9-11. — Gearless tilt.



91.434
Figure 9-12.—Cycle shaft and latch bail.

The right cam (the "5-unit cam") can be disregarded for the moment. The cycle shaft powers the positioning of the type head by operating the selector latch bail. The latch bail is a box-shaped frame located just beneath the cycle shaft. Two short arms for the frame extend forward where they pivot on a shaft mounted to the powerframe. Each side of the latch bail contains a roller that is constantly in contact with its cycle shaft cam. An extension spring at the rear of the latch bail applies a constant upward pressure to hold the rollers against the cams. Each time the cycle shaft operates 180°, the bail is forced down at the rear, pivoting about the bail shaft.

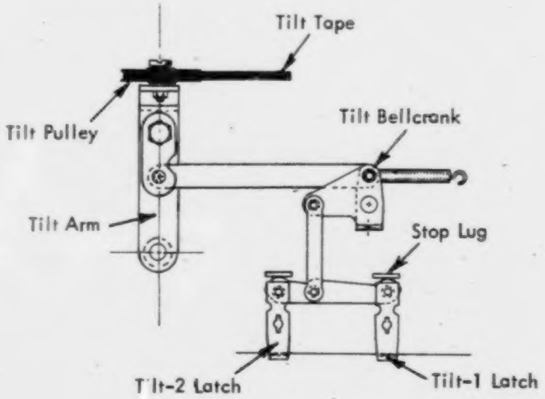
Now look at figure 9-13. The rear of the latch bail is recessed at six points. Five of the recesses contain selector latches. The sixth recess is for special applications of the machine. Across the rear of the latch bail is a plate attached by four screws. Each selector latch has a lip formed to the rear just under the bail plate. An extension spring holds each latch to the rear. The five selector latches are components of the differential lever assembly that determines how much tilt and rotation the head receives. The two latches to the left tilt the head, while the three on the right rotate the head. If the latches remain to the rear under the plate, they are pulled down when the bail is operated. If any latch is held forward, it is not hooked under the bail plate and is not pulled down during an operation of the latch bail. The method of pulling the various latches forward is discussed in a later section.



91.435
Figure 9-13.—Latch bail—side view.

TILT DIFERENTIAL.—The two tilt latches, shown in figure 9-14 are attached at each end of a short lever by ball shouldered rivets. The ball shape of the shoulders allows the latches to pivot in all directions. The lever is attached by a double vertical link to the tilt bellcrank. The bellcrank pivots on a stud at the top of the differential bracket. The connection of the double link is not in the middle of the lever; therefore, the movement developed by one tilt latch is greater than that of the other. A horizontal link connects the top of the tilt bellcrank to the tilt arm. Operation of the bellcrank forces the tilt arm to the left and exerts a pull on the tilt tape.

The tilt arm is sometimes referred to as the tilt multiplying arm, because the movement of the horizontal link is increased at the pulley due to the leverage developed. The left tilt pulley is mounted to the tilt arm on a ball-shouldered pivot screw allowing the pulley to float. This allows the pulley to remain horizontal regardless



91.436
Figure 9-14.—Tilt differential at rest.

of the position of the tilt arm. It must remain horizontal to prevent the tilt tape from coming off the pulley.

Look at figure 9-15A The tilt bellcrank is rotated by a pull on the tilt latches. When the left latch is held to the front, the right one remains to the rear, and only the right latch is forced down by the latch bail. As the latch pulls down on its attached lever, the left end of the lever pivots against a stop lug formed out from the differential bracket. The vertical link from the lever is then pulled to operate the tilt bellcrank. The same action occurs if the left latch is pulled down by the latch bail while the right latch is held forward. The distance the vertical link is pulled is not the same for both latches, because the link is not connected to the middle of the lever.

When only the right latch is operated by the bail, the left end of the lever is not pulled down and acts as a pivot point. The vertical link is attached to the lever one-third of the distance from the pivot point to the right latch. This causes the link to be pulled down only one-third as far as the latch is pulled by the bail. The movement of the link is sufficient to cause the type head to tilt a distance of one band of characters. This places the second bank from the top in the printing position. When only the left latch is operated, the right end of the lever acts as a pivot point, as illustrated in figure 9-15B. Vertical link is then two-thirds of the distance from the pivot point to the operating latch and is moved two-thirds as much as the latch. This movement is sufficient to cause the type head to tilt a distance of two bands of characters. The third band is then in the printing position.

When both latches remain to the rear under the latch bail, as they are in figure 9-15C both are operated. The lever moves straight down and neither end acts as pivot point. This causes the double vertical link to receive the same motion as the latches, resulting in three character bands of tilt. The fourth band is then in the printing position. When operated by itself, the right tilt latch causes a tilt of one character band; therefore, it is referred to as the tilt-1 latch. Because the left latch causes a tilt of two character bands, it is called the tilt-2 latch. Both latches operated together cause a tilt-3 action.

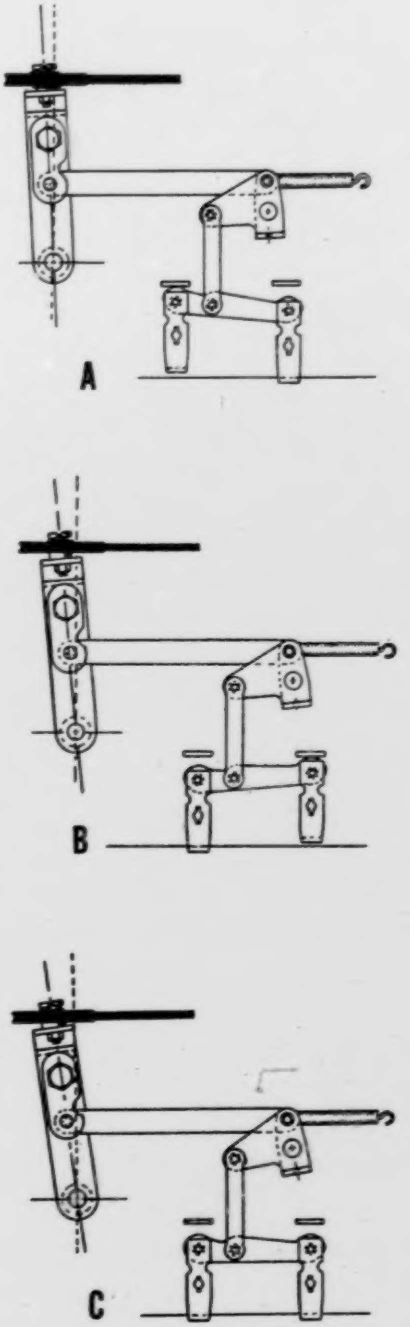


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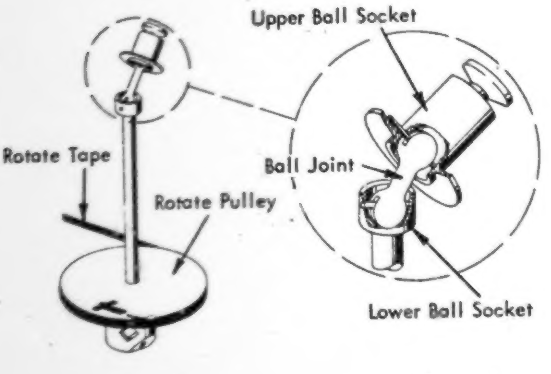
Figure 9-15. — Tilt operations.



91.438
Figure 9-16.—Rotate mechanism—rocket portion.

ROTATE MECHANISM

The rotate mechanism positions the rear of the type head left or right to the desired character within a tilt band. The upper ball socket to which the type head is attached, has a shoulder at the bottom fitted into a hole in the tilt ring. The fit is very close, yet permits free rotary motion of the upper ball socket. The upper ball socket is held in place by the tilt ring spacer. The spacer is attached directly to the tilt ring and fits around a flange of the upper ball socket. The tilt ring spacer is shimmed to allow rotation of the upper ball socket, yet restrict up and down play. Look now at figure 9-16 and you will see that the underside of the upper ball socket is hollow and forms the socket for a ball joint connection. A dog-bone-shaped ball joint fits into the socket over a pin that extends through the socket. The ball joint is identical at both ends. The lower end fits over a pin in the lower ball socket. These two ball and socket connections act as universal joints to permit the type head to be rotated and tilted at the same time. The rotate shaft operates directly inside the hollow of the yoke.

The bottom of the shaft pivots in a hole in a plate attached to the bottom of the rocker. This plate acts as a bearing for the bottom of the rotate shaft. Attached near the bottom of the shaft is the rotate pulley, similar in operation to the tilt sector pulley. By means of the upper and lower ball sockets and the ball joint, the rotate pulley operates to rotate the type head in either direction.

As on the tilt mechanism, the rotate pulley, (fig. 9-17), is operated by a steel tape that passes around two side pulleys and attaches to the carrier. When either of the side pulleys moves away from the other, the type head is rotated counterclockwise by the pull of the tape. When either side pulley moves toward the other, the type head is rotated clockwise by the tension of the rotate pulley spring. The rotate spring is of the mainspring type enclosed in a stationary cage with the outer end of the spring attached to the cage. The inner end of the spring is connected to a hub on the rotate pulley. A spring of this type must be used here rather than an extension spring, as is used on the tilt sector pulley, because the type head is required to rotate almost a full revolution.

The right-hand rotate pulley is attached to the shift arm and moves only during the shift operation; therefore, consider it to be stationary for the present. The left-hand rotate pulley is attached to the rotate arm. When the arm moves away from the sideframe, it exerts a pull on the tape to rotate the type head counterclockwise. This direction is known as the positive direction of rotation. When the left-hand rotate pulley moves toward the sideframe, the rotate spring turns the rotate pulley and rotates the type head in a clockwise direction. This direction is known as the negative direction of rotation.

POSITIVE ROTATE DIFERENTIAL. — The rotate differential is much the same as the tilt differential. The latches are operated by the latch bail if they are allowed to remain to the rear under the bail. Each operates with a different leverage for different amounts of rotation. Rotation of up to five characters is sometimes required on either side of the rest position. This requires more latches and levers than for a tilt operation.

Look at figure 9-18A and consider first the positive rotation of the type head. Three latches and a series of three levers are involved in positive rotation. The three latches are those farthest to the right in the latch bail. All the latches are spring-loaded to the rear under the latch bail and are operated by the bail unless they are pulled forward. The two latches-on the extreme right are mounted by ball-shouldered rivets to a short lever similar to the tilt latch mounting.

A flat double link extends vertically from the lever to a second lever above it. The connection is at the right end of the second lever and one-third of the distance from the right

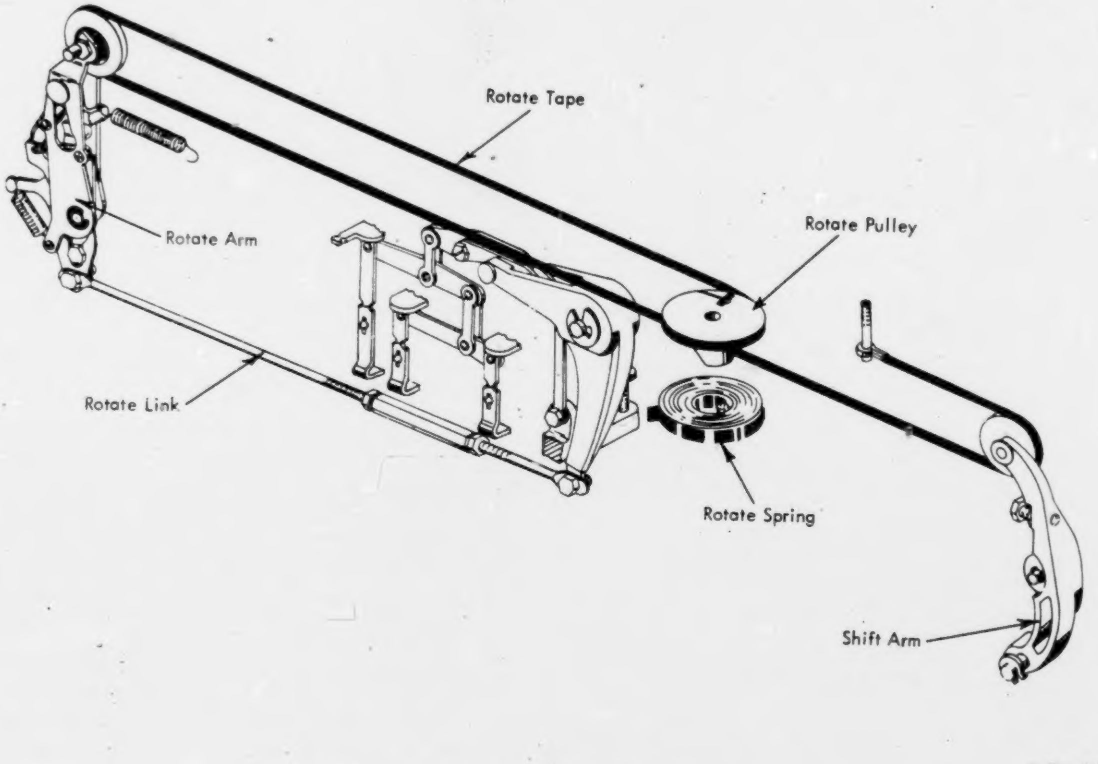


Figure 9-17.—Rotate tape system.

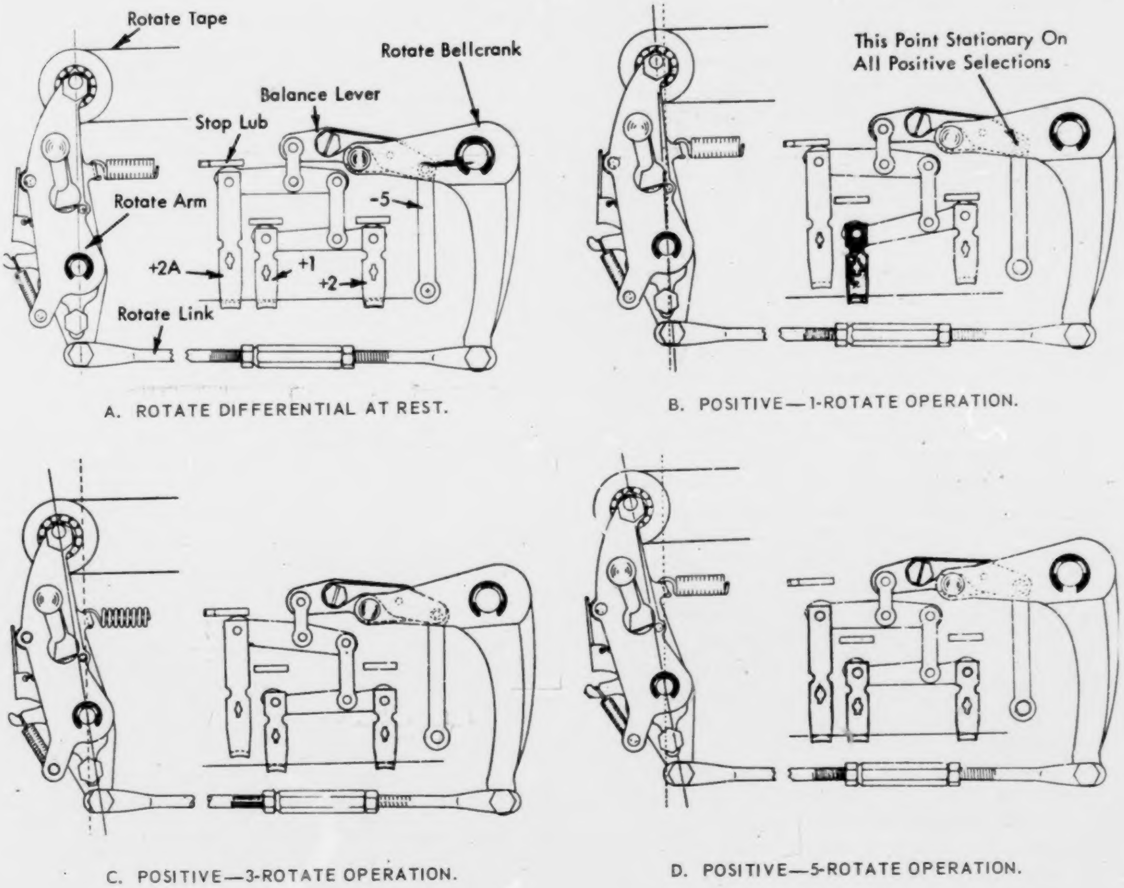
91.439

end of the first lever. The third latch is connected by a ball-shouldered rivet to the left end of the second lever. Becuase its mounting point is higher than the other latches, the third latch is much longer than the others to permit latching under the bail at the bottom.

A second vertical link connects the second lever to the left end of the third lever in the series. The link is attached to the second lever two-fifths of the distance from the right end. The third lever is an adjustable lever connected at the middle to the horizontal arm of the rotate bellcrank. It is referred to as the balance lever, because its adjustment balances the amount of motion between positive and negative rotation. The right end of the balance lever is held stationary during positive rotation. A downward pull at the left end causes the rotate bellcrank to operate. A heavy link connects the bottom of the rotate bellcrank to the bottom of the rotate arm. The rotate arm is sometimes referred to as the rotate multiplying arm, because the movement of the rotate link is increased at the pulley as a result of the leverage. Operation of the bellcrank counterclockwise causes the rotate arm to pivot about its fulcrum point and exert a pull on the rotate tape.

Look at figure 9-18B. In order to operate the balance lever, one or more of the latches must be pulled down by the latch bail. Consider the latches one at a time, starting with the middle of the three rotate latches. When only the middle latch is allowed to remain under the latch bail, it is the only one pulled down when the bail operates. As the middle latch is pulled down, its attached lever moves down at the left and pivots at the right on a stop lug formed out from the differential bracket. The vertical link is attached to the lever one-third of the distance from the pivot point to the latch. This causes the link to be moved down one-third as much as the latch.

The link exerts a pull on the right end of the second lever, causing it to pivot on its



A. ROTATE DIFFERENTIAL AT REST.

B. POSITIVE—1-ROTATE OPERATION.

C. POSITIVE—3-ROTATE OPERATION.

D. POSITIVE—5-ROTATE OPERATION.

91.440

Figure 9-18.—Rotate operations.

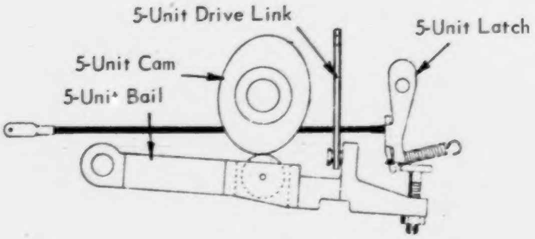
stop lug at the left end. The second vertical link is attached to the lever three-fifths of the distance from the pivot point to the operating end of the lever. The second link moves three-fifths as much as the right end of the lever. The right end of the second lever moves one-third as much as the latch. Multiplying the two together, the second vertical link moves three-fifteenths, or one-fifth as much as the latch. The second vertical link operates the left end of the balance lever, which in turn actuates the rotate bellcrank. This movement is sufficient to cause a positive rotation of one character on the type head. The movement is caused by the operation of the middle rotate latch, so it is referred to as the rotate-1 latch.

When only the right-hand latch is operated, the movement of the rotate bellcrank is doubled, and a positive rotation of two characters is obtained on the type head. The increased movement is obtained at the first lever. When the right-hand latch moves down, the lever pivots on a stop lug at the left. The vertical link is attached two-thirds of the distance from the pivot point to the latch; therefore, the link moves down two-thirds as much as the latch. This is twice as much as for the rotate-1 latch. The right-hand latch is referred to as the rotate-2 latch.

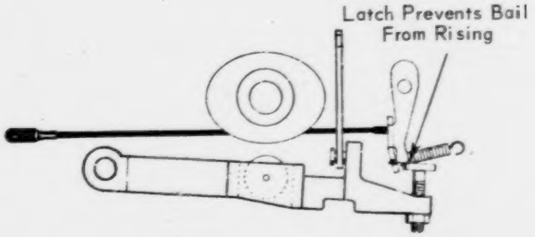
Now in figure 9-18C the drawing shows that when both the rotate-1 and rotate-2 latches are operating together, the first lever moves straight down without pivoting at either end. This gives the same amount of motion to the first vertical link as is given to the two latches. Movement of the link is three times as much as when operated by the rotate-1 latch alone. The additional movement is transferred to the rotate bellcrank to rotate the type head three characters in the positve direction. When additional rotation is required the third rotate latch must be used.

The left-hand latch is never used alone; but to clarify its leverage in relation to the other latches, consider it to be the only one in operation. The left-hand latch is attached directly to the end of the second lever. When operated, the latch causes the left end of the second lever to move down. The right end of the lever cannot rise, so it acts as a pivot point. The second vertical link is attached to the lever two-fifths of the distance from the pivot point to the latch; therefore the link moves down two-fifths as much as the latch. Movement of the link is twice as much as when the rotate-1 latch is operated alone. Therefore, the movement obtained from the left-hand latch is sufficient to rotate the type head two characters in the positive direction. Since the right-hand latch is called the rotate-2 latch, the left-hand latch is referred to as the rotate-2A latch.

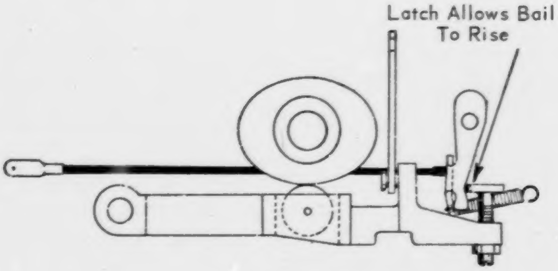
Look at figure 9-18C. The 2A latch is never used by itself. When its motion is added to that of one or both of the other latches, rotation of four or five characters can be obtained. The rotate-1 latch is used for one-character rotation and the rotate-2 latch for two-character rotation. Both are operated together for three-character rotation. The rotate-2 and rotate-2A latches are operated for a four-character rotation. The rotate-1, rotate-2, and rotate-2A are operated for a five-character rotation.



A. BAIL AT REST.



B. POSITIVE ROTATE CYCLE.



C. NEGATIVE ROTATE CYCLE.

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Figure 9-19.—5-unit bail.

NEGATIVE ROTATION.—Positive rotation of the type head is achieved by operating the rotate bellcrank counterclockwise so as to create a pull on the rotate tape. If follows then that operating the rotate bellcrank clockwise allows the rotate pulley spring to rotate in a negative direction. The rotate bellcrank is controlled by the balance lever in the differential series. In order for the bellcrank to operate clockwise, the balance lever must be raised. The left end of the lever cannot rise because the stop lugs on the bracket prevent any upward movement in the lever series. Therefore, if the bellcrank is to operate clockwise, the right end of the lever must be raised. The right end of the balance lever has a flat link connection (5-unit drive link) to the 5-unit bail assembly, which is shown in figure 9-19A. The bail is a single arm located under the cycle shaft and pivoted in front on the bail shaft. When the 5-unit bail is allowed to rise, the right end of the balance lever rises to allow clockwise operation of the rotate bellcrank.

The 5-unit bail is prevented from rising by the 5-unit latch at the rear, as illustrated in figure 9-19B. The latch is mounted to the differential bracket and pivots front to rear. In the rest position, the latch is positioned above the head of an adjusting screw at the rear of the 5-unit bail. When the latch is pulled forward the bail is allowed to rise, as shown in figure 9-19C. The force which raises the bail comes from the rotate pulley spring and the spring attached to the rotate arm. These springs are applying a constant force on the rotate bellcrank in the clockwise direction.

The 5-unit bail is restored down by the extreme right-hand cam on the cycle shaft. The high point of the cam is 90° from the high point of the other two cams. This insures that when the latch bail is driven down in the active position, the 5-unit bail can be up in the active position. Conversely, when the latch bail is up in the rest position, the 5-unit bail is down in the rest position. Note that the 5-unit bail is held down in the rest position by the cam rather than by the 5-unit latch. In the rest position, there is a clearance between the latch and the adjusting screw in the 5-unit bail. The clearance must be present to insure resetting of the latch at the completion of a cycle. During a positive rotate or nonrotate cycle, the 5-unit bail rises slightly before being restricted by the 5-unit latch, which is shown in figure 9-19B. This upward movement of the 5-unit bail allows a slight clockwise, or negative rotation, of the type head. The type head rotates from the rest position to a position known as the latched-home position. Consider all positive and negative rotations to occur from the latched-home position.

Look now at figure 9-20A. Movement of the 5-unit bail from the latched-home point to the low point of the cam allows sufficient clockwise movement of the rotate bellcrank to permit a 5-character negative rotation of the type head. If less than five units of negative rotation is desired, it is necessary to pull down on the left end of the balance lever as the right end goes up. This reduces the amount of clockwise movement of the rotate bellcrank. Operating one or more positive rotate latches down in conjunction with allowing the 5-unit bail to rise allows different amounts of negative rotation. The positive rotate-1 and negative-5 combine to allow a negative-4 rotation. A positive-2 and negative-5 combination gives a negative-3 rotation. This is illustrated in figure 9-20B. A positive-3 and a negative-5 operation gives a negative-2 rotation. A positive-4 plus a negative-5 combination gives a negative-1 rotation.

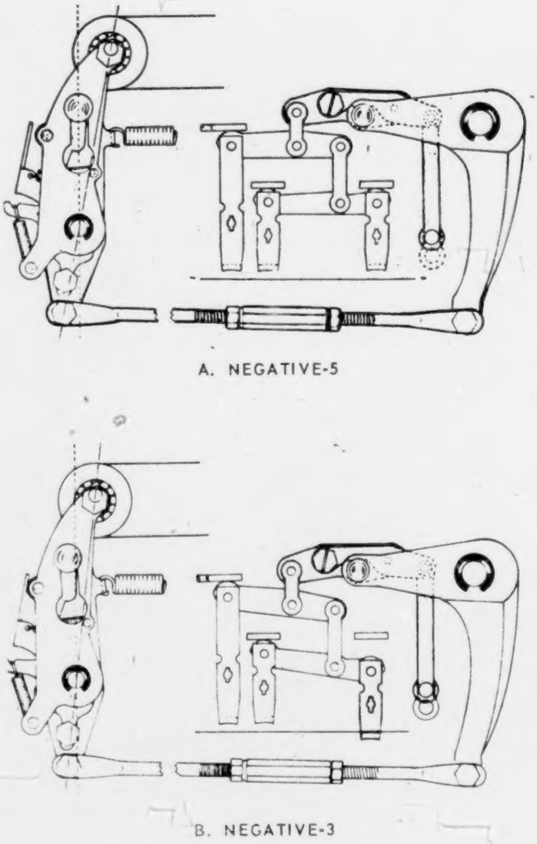

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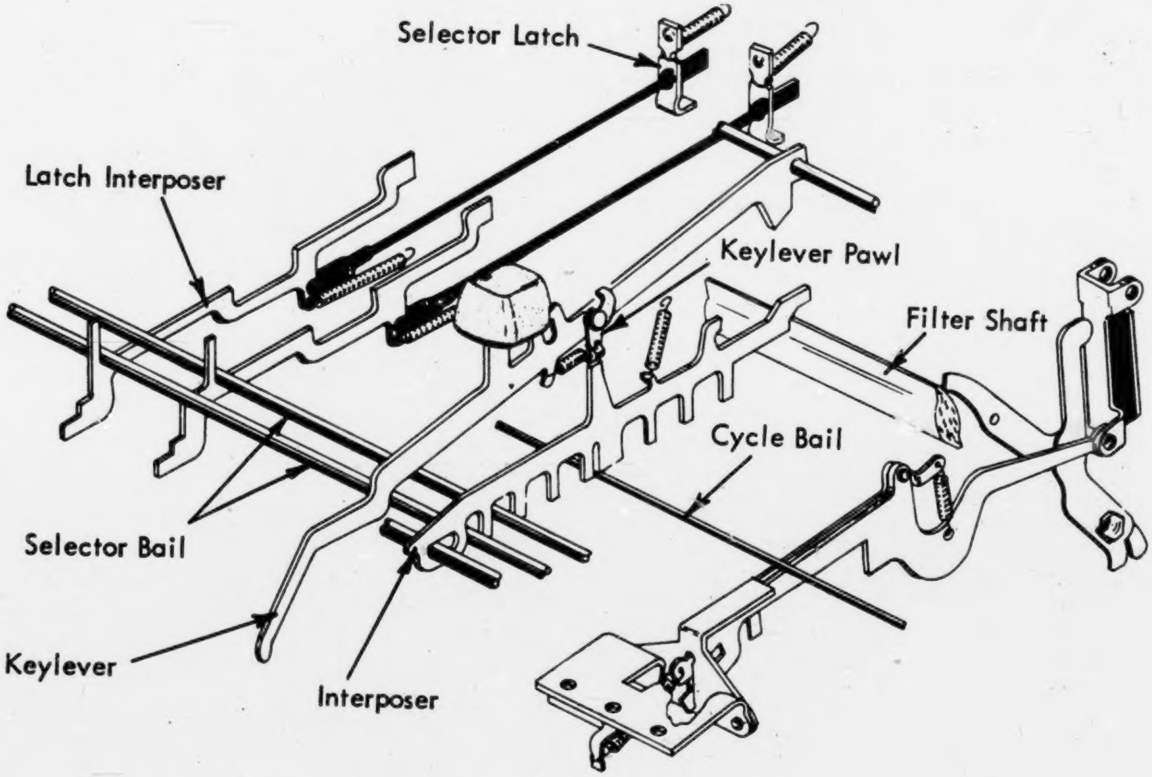
Figure 9-20.—Negative operations.

KEYBOARD SECTION AND CHARACTER SELECTION

The keyboard section is a compact unit that is detachable as a unit from the rest of the machine. Contained in the keyboard section are all the keylevers and allied parts and a selection mechanism for the differential latches. Depression of a letter keylever prepares the selection mechanism for operation and tops the cycle clutch latch to allow a cycle operation.

KEYLEVERS.—The keylevers pivot on a fulcrum rod at the rear of the keylever. Nylon rods at the top and bottom of the guide comb slots limit the travel of the keylevers in the front



91.443

Figure 9-21.—Keyboard section and character selection.

guide comb. A lower extension on each keylever operates in the keylever bearing support to stabilize the keylever. The extension is illustrated in figure 9-21.

The keybuttons are designed in the shape of a pyramid to make use of a keyplate unnecessary. The tops of the keybuttons form a concave slope to the keyboard for ease of operation. Keylever tension is supplied by a set of flat spring fingers under the front of the keylevers. The forward end of each spring finger is cupped so that the spring will maintain—its position under the keylever. Different spring tension is supplied to the four rows of letter keylevers by auxiliary leaf springs under the keylever springs. The auxiliary spring fingers vary in length to offset the leverage difference among the four rows of keylevers. This variation in spring tension results in a uniform operating force requirement for all keylevers.

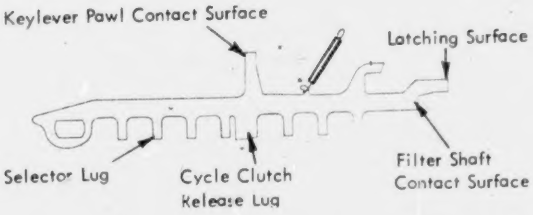
A shoulder rivet attaches a keylever pawl to each keylever at the rear. A small spring attached from the pawl to the keylever holds the pawl in the rest position. The pawl extends below and is formed under the keylever in position to strike the top of an interposer. Adjusting lugs at the rear of the keylevers make it possible to adjust the relative height of each individual keylever and keylever pawl.

INTERPOSERS.—Still referring to figure 9-21, we see that each keylever has a character interposer located just below it. The purpose of the interposers is to select the amount of tilt and rotate needed to bring the desired character to the printing point. A large fulcrum rod passes through an elongated hole in the front of each interposer and provides a support on which the interposers can pivot and slide. A guide comb at the front and rear separates the interposers. The interposers are allowed to move up and down in the rear guide comb as well as front to rear. An extension spring from each interposer to the top of the rear guide comb loads the interposer to the rear and up into the rest position.

The interposers have several lugs extending from them, each with its own operation to perform. These lugs are shown in figure 9-23. Each interposer has a lug on top in position to be struck by the keylever pawl. On the bottom of the interposers are positions for eight lugs. Seven of the lugs are selective lugs. The absence of presence of these lugs in different position combinations makes the interposers different. There are no two alike. The rearmost selective lug is for special applications of the machine.

One lug on the bottom is common to all interposers. It is a wide lug located at the middle of the interposers. Its purpose is to release the cycle clutch for a cycle operation whenever a keylever is depressed. Directly below the lug is the cycle bail, shown in figure 21, that pivots up and down. Downward movement of any character interposer forces down on the cycle bail to release the cycle clutch latch and allow a cycle operation. The cycle clutch release lug is cut at an angle on the bottom to prevent interference between the lug and the cycle bail as parts are restoring to the rest position.

FILTER SHAFT.—Still referring to figure 9-21, when the interposer is depressed, it pushes the cycle bail down to unlatch the cycle clutch and allows a 180° rotation of the cycle shaft. Rotation of the cycle shaft 180° also rotates the filter shaft 180°. The filter shaft is a two-bladed shaft located at the rear of the keyboard section and just below the ends of the interposer. It pivots in a bronze bearing at each end and is connected by a gear train on the left side of the cycle shaft. When an interposer is depressed, the rear of the interposer is moved down in front of one blade of the filter shaft. As the filter shaft turns, the blade drives the interposer forward to operate the character selection mechanism.

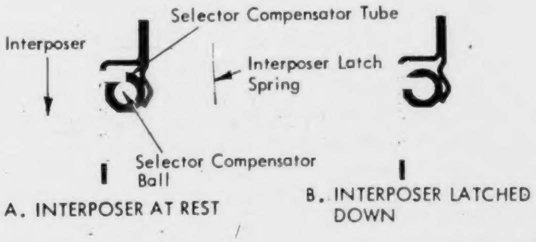


91.444

Figure 9-22.—Selector interposer.

INTERPOSER LATCH.—Look at figure 9-23 and you see resting against the rear of each interposer a spring finger called the interposer latch spring. The spring fingers are slightly deflected to the rear when the interposers are at rest. When any interposer moves down at the rear, the spring snaps forward over the interposer and holds it down. The interposer remains down until it is pushed forward enough to clear the spring finger. At that time it is raised and restored by its extension spring. An interposer must be latched down to insure that it remains in the path of the filter shaft blade until the cycle operation occurs. Unless latched down, the interposer could restore upward without being driven forward. With this latching device, one interposer can be latched down just as the previously depressed interposer is being operated forward. The second interposer is then operated forward as soon as the cycle operation for the first interposer is completed. This is known as character storage and tends to even erratic typing rhythm.

SELECTOR COMPENSATOR.—Again referring to figure 9-23, we can see how the selector


Selector Compensator Tube
Interposer
Interposer Latch Spring
Selector Compensator Ball
A. INTERPOSER AT REST
B. INTERPOSER LATCHED DOWN

91.445

Figure 9-23.—Interposer latch and selector compensator.

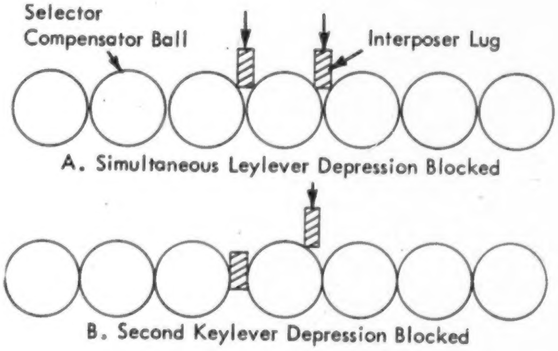
compensator prevents simultaneous depression of two keylevers. Ensuring that only one interposer at a time can be operated down and then forward. If more than one interposer at a time were depressed, they would be operated forward together and a selection error would result, causing the wrong character to print. A hook-shaped lug at the rear of each interposer operates in a device called the selector compensator, which is attached to the rear interposer guide comb. The compensator contains closely spaced steel balls that prevent downward movement of two or more interposers simultaneously, as illustrated in figure 9-24A.

When an interposer is down, the steel balls shift in the tube of the compensator to block the downward movement of any other interposer, as illustrated in figure 9-24B. Look back at figure 9-23 and you see that the hook portion of the interposer lug extends to the rear just to the center line of the steel balls. When an interposer is driven forward after being depressed at the rear, the lug is no longer between the steel balls, and another interposer can be depressed. With this arrangement, the operator does not have to wait until an interposer is restored upward before actuating another.

An adjustable stop at each end of the compensator tube keeps the balls somewhat centered between the interposers. The balls are thus prevented from shifting too far left or right. If the balls were allowed to move too far under the interposer lugs, they would partially block the depression of an interposer and the keyboard touch would suffer. The stops are removable so that the steel balls may be removed and cleaned if necessary.

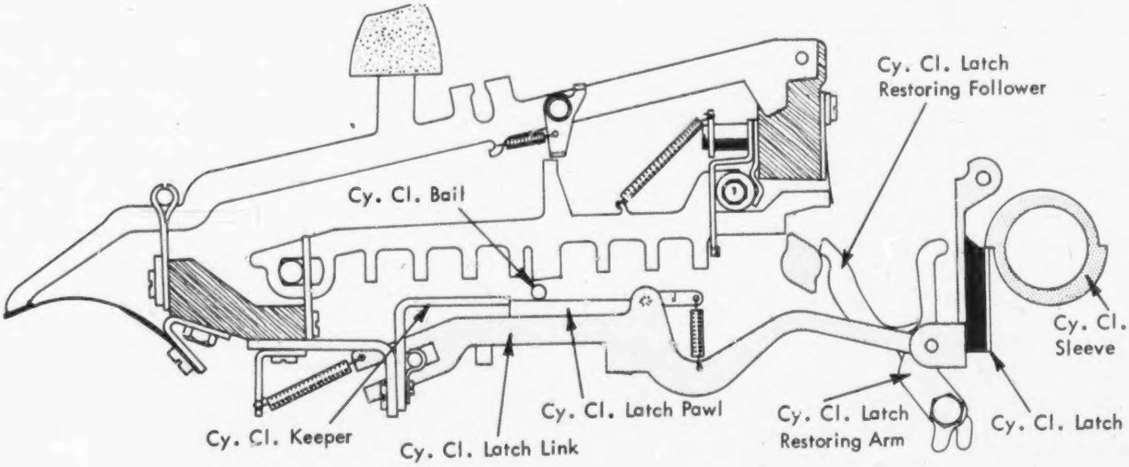
SELECTOR BALLS AND LINKS. — Now refer back to figure 9-21, and we will discuss the selector bails. Six selector bails are mounted between the side frames so they can operate forward and backward. Each bail is in front of a selector lug position on the interposers. When an interposer containing all its lugs is driven forward, all the selector bails are moved forward. If any lug is absent from an interposer, the bail for that position is not operated forward by that interposer. Six sliding interposers, called the latch interposers, are located under the left end of the selector bails. These interposers operate front to rear in the bottom of the interposer guide comb. Each latch interposer has a lug that extends up directly in front of a selector bail.

As the selector bail moves forward, it moves the latch interposer forward. The bails and latch interposers are paired so that each bail operates only one interposer. An extension spring at the bottom of each latch interposer loads the interposer and its selector bail to the rear. The latch interposers rest against adjustable lugs at the rear to prevent the bails from being forced against the selector interposer lugs. This prevents the selector interposers from being against the bails as the interposers are depressed. The stop lugs help prevent the selector bails from bouncing as they are restored to the rear. An adjustable link connects each latch interposer to one of the selector latches of the differential mechanism. When a latch interposer is moved forward, the selector latch connected to that interposer is pulled forward to prevent its being operated downward by the latch bail.


Selector
Compensator Ball
Interposer Lug
A. Simultaneous Leylever Depression Blocked
B. Second Keylever Depression Blocked

91.446
Figure 9-24. — Selector compensator action.

CYCLE CLUTCH LATCH. — Look at the cycle clutch mechanism in figure 9-25. Although not actually a part of the keyboard section, the cycle clutch latch is directly related to the keyboard mechanisms. It is through depression of a keylever that the cycle clutch is allowed to operate. The cycle clutch latch pivots on a bracket at the front of the powerframe. It pivots from the top and rests in a vertical position just in front of the cycle clutch sleeve. A thin metal plate mounted in rubber on the rear of the latch prevents rotation of the sleeve, thereby preventing the cycle clutch spring from tightening on the cycle clutch pulley hub. The latch is held in this position by the cycle clutch latch pawl and link assembly that extends forward from the latch. The cycle clutch pawl pivots on the link. An extension spring between the


Cy. Cl. Latch
Restoring Follower
Cy. Cl. Bail
Cy. Cl. Sleeve
Cy. Cl. Latch Pawl
Cy. Cl. Latch
Restoring Arm
Cy. Cl. Latch
Cy. Cl. Keeper
Cy. Cl. Latch Link

91.447

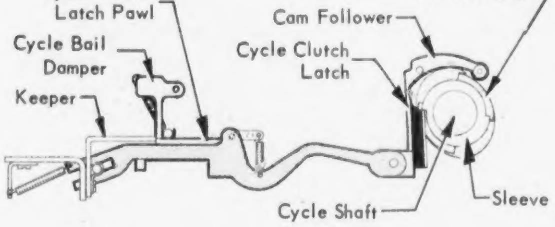
Figure 9-25.—Cycle clutch latch mechanism.

two parts rotates the front of the pawl up into a latched position behind the cycle clutch keeper that we see in figure 9-25.

The cycle clutch keeper is an additional plate, mounted on the cycle clutch keeper bracket, which is attached to the guide comb support under the front of the keyboard section. An extension spring exerts a pull toward the front on the cycle clutch latch link. The pawl, being attached to the link, prevents the link from being pulled forward. When the keylever is depressed, the interposer beneath the keylever forces the cycle bail to pivot downward. The cycle bail moves the cycle clutch latch pawl down, disengaging it from the keeper. The extension spring at the front of the link is then allowed to snap the link and cycle clutch latch forward disengaging the latch from the clutch sleeve. This allows the clutch spring to tighten and begin a cycle operation.

A small lever, called the cycle bail damper, shown in figure 9-26 pivots at each side of the keyboard just above the cycle bail. An extension of each lever rests against the front of the bail. An extension spring connected between the cycle bail and each damper has the dual purpose of restoring the cycle bail upward and holding the damper against the bail. The purpose of the damper is to lightly retard the upward movement of the cycle bail so as to prevent the bail from bouncing as it reaches its upward limit. Without the dampers the bail has a tendency to bounce down and retrip the cycle clutch, creating an additional cycle.

RESTORING MECHANISM.—Now, in figure 9-26 we see that the cycle clutch latch restoring mechanism consists of a cam and a cam follower. The cam, called the cycle clutch latch restoring cam, is a double-lobed cam mounted on the cycle shaft. The cam follower is an extension of the cycle clutch latch, which protrudes to the rear of the machine just above the restoring cam. The extension has a small adjustable steel roller mounted on it which rides on the cam during a restoring operation. When the machine is at rest, the low point of the


Cycle Clutch
Latch Pawl
Cycle Bail
Damper
Keeper
Restore Cam
Cam Follower
Cycle Clutch
Latch
Sleeve
Cycle Shaft

91.448

Figure 9-26.—Cycle clutch latch restoring operation (new style).

restoring cam is directly below (but not in contact with) the steel roller. When a keylever is depressed, the cycle clutch latch pawl is pushed off its keeper, allowing the cycle latch to swing forward and release the cycle clutch sleeve. When the cycle clutch latch swings forward, the steel roller on the extension drops down onto the restoring cam. As the cam rotates toward its high point, the steel roller is forced up, swinging the cycle clutch latch to the rear into the path of the cycle clutch sleeve. The latch is restored far enough to the rear to permit the cycle clutch latch pawl to reset on its keeper.

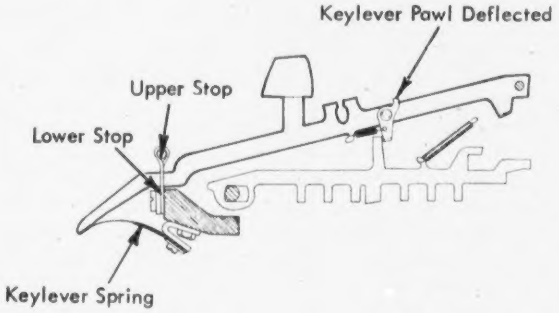
KEYLEVER OPERATION.—Depression of a letter keybutton causes the front of the keylever to move down as the rear end pivots about the fulcrum rod. The keylever pawl at the rear of the keylever contacts the top lug of an interposer. Further movement of the keylever causes the rear of the interposer to move down as the front pivots about the interposer fulcrum rod. As the interposer moves down, a lug on the bottom of the interposer forces the cycle bail and the cycle clutch latch pawl down. Further movement of the interposer allows the interposer latch spring to snap forward over the top of the interposer to maintain its downward position.

At about the same time that the interposer latches down, the cycle bail trips the cycle clutch pawl off its keeper to allow the cycle clutch to begin an operation. As the cycle shaft turns, the cams of the cycle shaft force the latch bail down. However, the contour of the cams is designed so that cycle shaft rotation does not cause immediate downward movement of the latch bail. During the "dwell" on the cycle shaft cams, the filter shaft is operated to drive the depressed interposer forward. As the interposer is driven forward, the selector lugs that are present on the interposer push their respective selector bails forward. The bails cause the latch interposers to pull the selector latches forward.

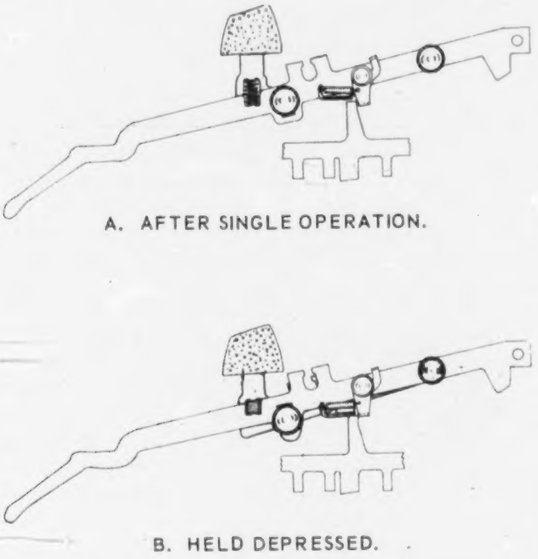
As the selector mechanism is being operated forward, the cycle shaft cams start to force the latch bail down. All latches that remain to the rear are operated down by the latch bail. (This does not apply to the negative-5 latch, which must be pulled forward in order to allow a negative rotation.) The latches are pulled forward only for an instant. As soon as the interposer has been pushed forward far enough to clear its interposer latch spring, it becomes free to restore vertically. The fact that the interposer cannot move up instantly out of the path of the filter shaft allows it to be driven farther forward. The interposer spring then raises the interposer and restores it to the rear. This allows the latches to restore to the rear. By this time the latch bail has been forced down by the cycle shaft cams far enough to prevent resetting of the latches under the bail plate. The latches merely rest against the bail plate until the cycle operation has been completed and the latch bail has restored. The same action applies to the negative-5 latch, except that its bail is allowed to rise in the operation position. The negative-5 latch resets above its bail when the bail has been driven to its rest position.

Look at figure 9-27. If the keylever has been held down throughout the operation, the rear edge of the interposer lug strikes the keylever pawl as the interposer restores to the rear. The keylever pawl is then deflected to the rear and remains in this position until the keylever is released. At this time it snaps forward above the interposer lug ready for the next operation. This arrangement insures a single operation regardless of how long the keylever is held depressed by the operator.

REPEAT/NONREPEAT KEYLEVERS.—Refer to figure 9-28A. A repeat/nonrepeat operation is provided as a standard feature in the hyphen/underscore position. The operation requires a special, two-piece keylever. One part of the keylever pivots about the keylever fulcrum rod at the rear and extends forward through the guide comb. It contains no keybutton but has the keylever pawl attached similar to the normal keylever. The second part of the keylever is a short lever containing the keybutton. It pivots on a shouldered rivet at the rear of the long keylever.



91.449
Figure 9-27.—Keylever held depressed.


A. AFTER SINGLE OPERATION.
B. HELD DEPRESSED.

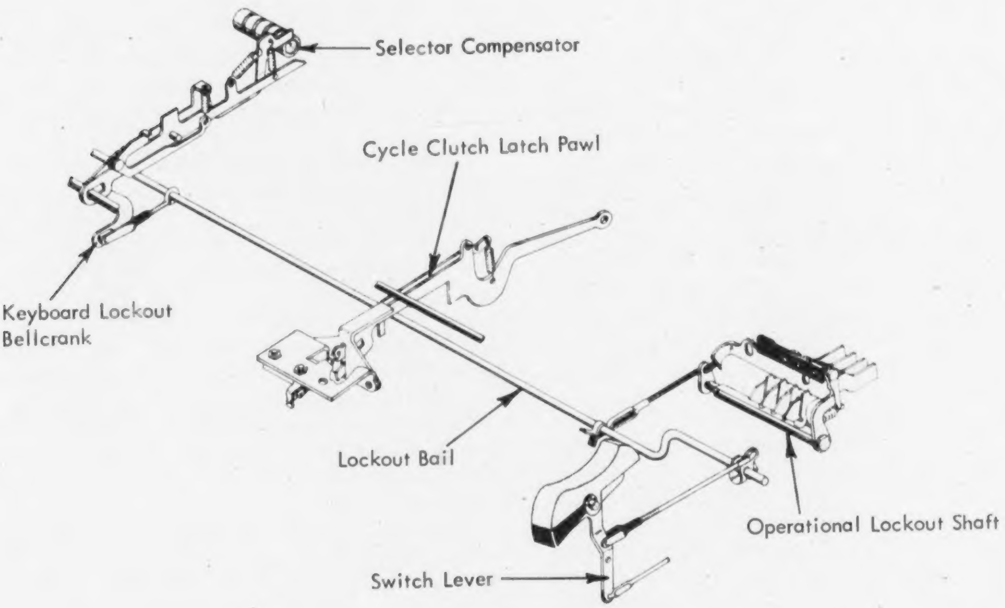
91.450

Figure 9-28.—Repeat keylever.

The front of the short lever is restricted by a shouldered rivet through an elongated hole. A compression spring between the two pieces holds the short lever up in its elongated hole.

When the keybutton is depressed the two pieces act as one, and a single operation results. If the keylever is held down, the keylever pawl is deflected to the rear as the interposer restores. Additional pressure applied to the keybutton overcomes the compression spring and causes the short lever to pivot downward. A special lug on the bottom of the short lever forces the interposer down for a second operation, as in figure 9-28B. The special lug is wide enough so that the interposer is not allowed to restore upward as long as the keylever is held in the repeat position. The interposer merely travels front to rear. As it does so, it prevents the cycle clutch latch pawl from resetting and results in a continuous operation. The repeat/nonrepeat feature may be removed from the machine by replacing the two-piece keylever with a conventional keylever.

KEYBOARD LOCK.—The drawing in figure 9-29 should help you to better understand the keyboard lock. When the switch is turned off,


Selector Compensator
Cycle Clutch Latch Pawl
Keyboard Lockout Bellcrank
Lockout Bail
Operational Lockout Shaft
Switch Lever

91.451

Figure 9-29.—Keyboard lock mechanism—ON position.

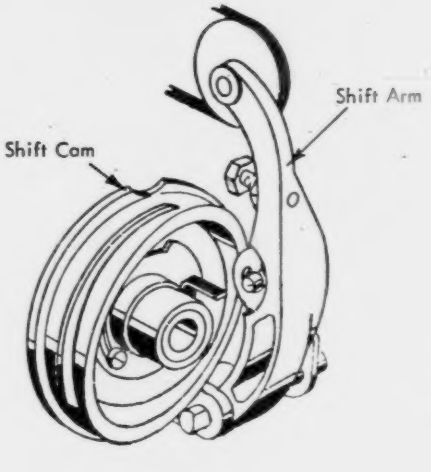
the keyboard must be locked to prevent mechanisms from being tripped while the motor is not running. This is to prevent the motor from having to start under a load and to prevent an unwanted operation the next time the switch is turned on. Operation of the switch lever controls the keyboard lock mechanism by rotating the lockout bail that extends across the bottom of the keyboard section. When the switch lever is in the OFF position, the lockout bail is moved forward into position below an extension of the cycle clutch latch pawl and prevents the cycle clutch from being released. As additional insurance against an interposer being latched down, a special bellcrank at the left side of the keyboard is rotated into the selector compensator by a link from the lockout bail. This forces the steel balls to shift in the tube and block the downward movement of all interposers. When the switch is on, the keyboard lock bellcrank is spring-loaded out of the selector compensator. A link from the right side of the lockout bail rotates a D-shaped shaft beneath the operational mechanism. The shaft locks the backspace, spacebar, carrier return, and indexing keylevers when the switch is off. The tab and shift keylevers are not locked.

SHIFT MECHANISM

The purpose of the shift mechanism is to rotate the type head 180° in the counterclockwise direction. This action places the uppercase hemisphere of the type head near the platen for typing capital letters. Each uppercase character is in the same tilt band as its lowercase counterpart but 180° from it. Thus, depression of a keylever with the shift in operation causes an uppercase character to print. The shift mechanism consists of a shift arm, shift cam, spring clutch control mechanism, and interlocks. The shift mechanism takes its power from the right end of the operational shaft. All the components are concentrated in that area.

SHIFT OPERATION.—Consult figure 9-30 and let's see how the shift operates by moving the right-hand rotate pulley toward the right. The movement of the pulley creates sufficient pull on the rotate tape to cause a 180° type head rotation. The pulley remains in this position as long as the shift keylever is held depressed.

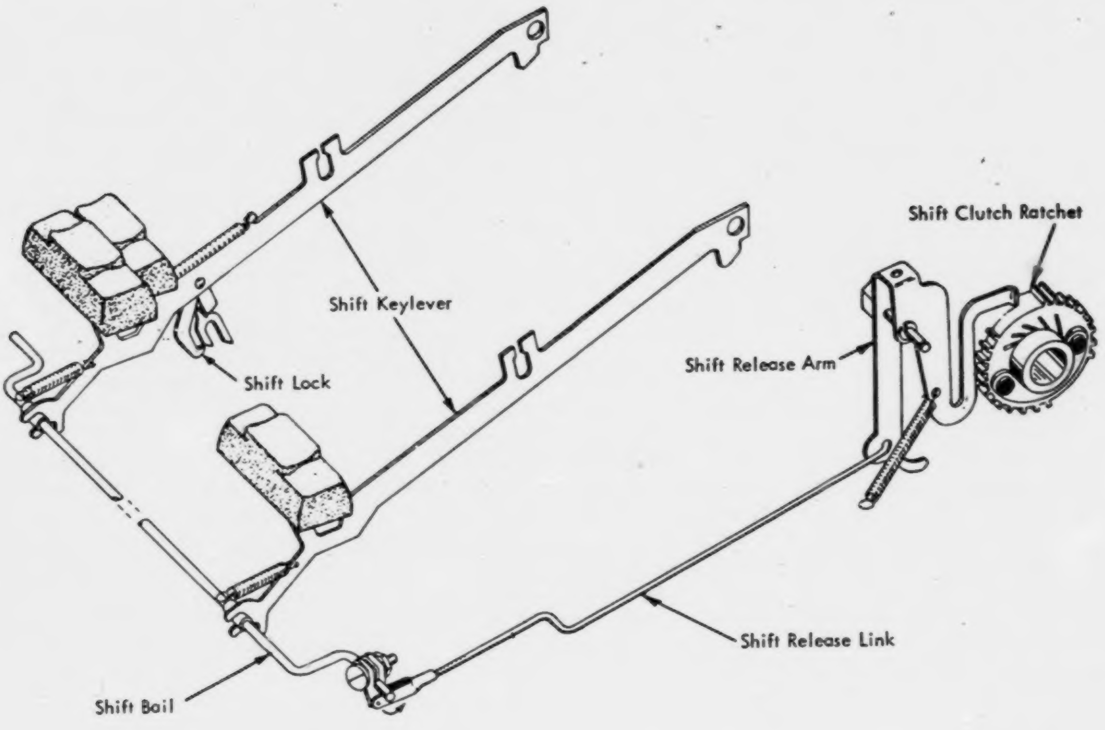
Two keybuttons, one at each front corner of the keyboard, can be used to actuate the shift mechanism. Now turn to figure 9-31 and you see that a bail between the two keylevers causes both of them to move together regardless of which one is depressed by the operator. If the operator desires to keep the mechanism in the uppercase position, a shift lock is provided for this purpose. The shift lock is attached to the keylever and may be locked by depressing the shift lock keybutton. The shift lock may be released by depressing and releasing either shift keybutton.



91.452
Figure 9-30.—Shift cam and shift arm.

Now, refer to figure 9-32 and notice that the right-hand rotate pulley is fastened to the top of the shift arm. The arm pivots left to right on a pin at the bottom. A strap from the shift arm to the pivot pin stabilizes the shift arm to minimize front to rear movement of the pulley. In figure 9-32A, we see that in the lowercase position, an adjustment screw near the top of the arm rests against the head of a mounting screw on the side of the powerframe. This shift arm must be forced to pivot outward for a shift operation. A disc-shaped shift cam fits around an extension of the operation shift bearing outside the sideframe.

The cam operates between two rollers located at the rear of the cam. The roller to the left of the cam is in a fixed position on the powerframe and serves as a backup roller for the cam. The roller on the right is attached to the shift arm and rides the camming surface of the cam. The camming surface is on the right side of the


Shift Clutch Ratchet
Shift Keylever
Shift Release Arm
Shift Lock
Shift Release Link
Shift Bail

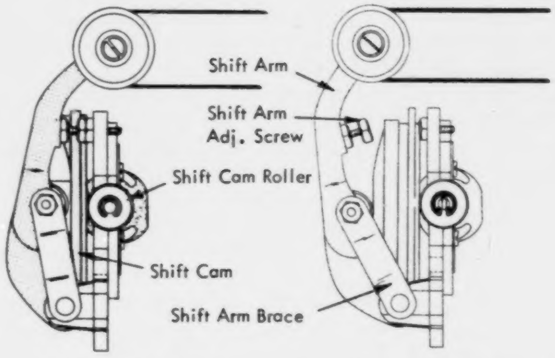
91.453

Figure 9-31.—Shift release mechanism.

cam rather than on the perimeter. When the low point of the cam is between the two rollers, the shift arm is in lowercase position. The cam is operated 180° to the high point in order to force the arm into uppercase position, as shown in figure 9-32B.

Look at the drawing in figure 9-33. The shift cam rotates only during a shift operation and receives its motion from the operation shaft. Since the operation shaft turns continuously when the motor is running, a clutch mechanism is required to engage and disengage the shift cam from the operation shaft when a shift operation is desired. A spring clutch "makes" and "breaks" the driving connection between the operation shaft and the shift cam.

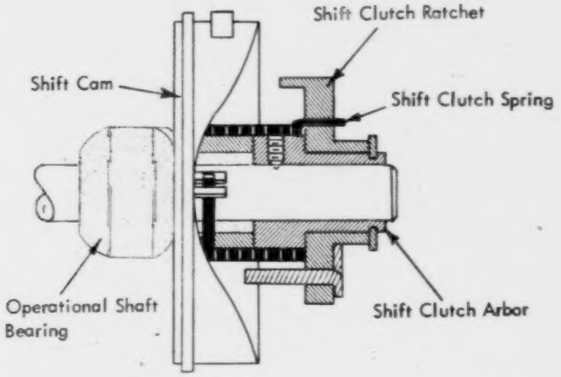
The shift cam mounts on a shoulder on the right-hand side of the operational shaft bearing and is free to rotate about this shoulder. The operational shaft extends through the center of this bearing beyond the right side of the shift cam. An arbor (shift clutch arbor) is setscrewed


Shift Arm
Shift Arm Adj. Screw
Shift Cam Roller
Shift Cam
Shift Arm Brace

A. LOWER CASE POSITION B. UPPER CASE POSITION

91.454

Figure 9-32.—Shift operation—rear view.



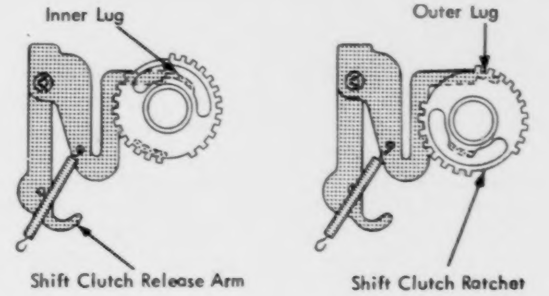
91.455

Figure 9-33.—Shift clutch.

to the shaft just to the right of the shift cam and turns with the shaft continuously. The drawing force to the shift cam comes from this arbor through a spring clutch that is fastened to the cam and encircles the arbor. The spring clutch is undersized and wound in the same direction that the arbor is turning. Therefore, anytime the spring clutch is allowed to collapse about the arbor it turns with the arbor, driving the cam. The cam is driven 180° each time a shift operation occurs.

Usually, a spring clutch is considered to be one that tightens when its driving hub turns in the direction that the spring clutch is wound and slips if the hub stops or rotates back in the opposite direction. This is not true of all spring clutches. In the shift mechanism, the driving hub (the shift clutch arbor) is rotating continuously in the direction that the spring clutch is wound. In order to stop shift cam, the spring clutch must be allowed to slip while the arbor continues to rotate. The only way to do this is to enlarge or expand the inside diameter of the spring clutch so that the driving action will stop. In the shift mechanism, the shift spring clutch must be held in the unwound position so that it is enlarged enough to allow the arbor to slip freely inside it. To enlarge the spring clutch, one end of the spring must be held while the other is rotated in the unwinding direction of the spring. The left end of the spring is formed out and fits into an adjustable plate attached to the cam. The right end of the spring is formed to the right and fits into a hole in the shift clutch ratchet. The shift clutch ratchet is a gearlike part mounted on the end of the shift clutch arbor. A large C-clip holds it in place. The arbor turns freely inside the ratchet when the shift is not being operated. Rotation of the ratchet counterclockwise causes the clutch spring to decrease in size. Conversely, if the ratchet is held stationary while the cam is rotated counterclockwise, the spring diameter increases.

The shift clutch ratchet has two lugs 180° apart on its left surface. One lug is nearer the center than the other and is referred to as the inner lug. The other lug is called the outer lug. The shift release arm, shown in figure 9-34A, is pivoted just in front of the cam and blocks the movement of the ratchet lugs to stop the rotation of the ratchet. The position of the shift release arm determines which lug of the ratchet will be stopped. The position of the shift release arm is controlled by a link from the arm to a lever attached to the end of the shift bail shown in figure 9-31. When a shift keylever is depressed, the bail rotates to force the link to the rear and operate the shift release arm. When the keylevers are at rest, the release arm is in position to stop the inner lug of the shift clutch ratchet. Depression of a keylever causes the release arm to rise out of the path of the inner lug into the path of the outer lug. When the inner lug is released, the clutch spring is allowed to decrease in diameter by its own spring tension. It then tightens around the rotating shift clutch arbor and the hub of the cam to drive the cam. The shift clutch ratchet rotates with the cam and clutch spring 180°. The outer lug of the ratchet then contacts the shift release arm, that



A. LOWER CASE POSITION B. UPPER CASE POSITION

91.456

Figure 9-34.—Shift clutch release arm.

has been raised into its path, and its rotation is stopped. The momentum of the shift cam causes it to rotate slightly farther. This further rotation causes the clutch spring to unwind and increase in diameter to allow the shift clutch arbor to slip freely inside the spring.

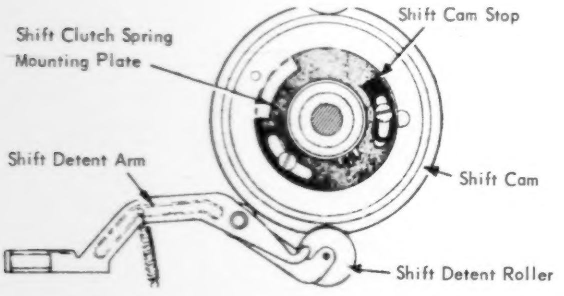
Once the shift cam's momentum has carried the cam far enough to properly disengage the spring clutch the cam must be restricted from overthrowing its rest position. Overthrow is controlled by the shift cam stop, shown in figure 9-35, which is attached to the cam and operates against the inner lug of the shift clutch ratchet. As long as the shift keylever is held depressed, the high point of the shift cam remains to the rear holding the shift arm to the right. When the keylever is released, the shift release arm moves down out of the path of the outer lug and back into the path of the inner lug. This allows the clutch spring to again tighten and drive the shift cam and ratchet 180° back to the lowercase position. The inner lug of the ratchet then contacts the release arm to disengage the spring clutch as before. The shift cam stop again controls overthrow of the cam.

Note that the shift cam stop always follows behind the inner lug of the ratchet when the ratchet and cam are operating. Whenever the ratchet is stopped by the release arm (on either lug), the momentum of the cam carries the stop further until the stop strikes the rear side of the inner lug. The horseshoe-shaped release arm, showin in B of figure 9-34 absorbs the shock of stopping the overthrow of the shift cam through the shift clutch ratchet.

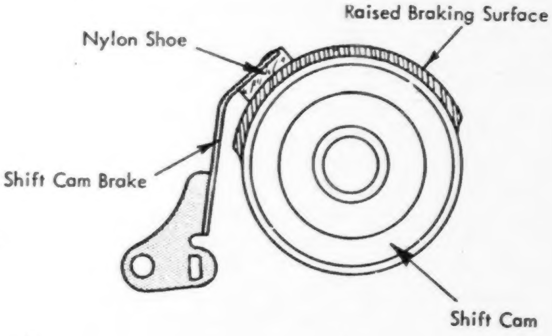
Back at figure 9-35 we see a small arm called the shift detent arm mounted on a pivot stud below and to the front of the shift cam. Although the detent arm's primary function is to operate the character interrupter mechanism, it is also used as a detent for the shift cam. As the cam approaches either the uppercase or lowercase position, a nylon roller mounted on the shift detent arm is spring-loaded into corresponding detent notches located on the outside surface of the cam. This helps to place the cam in its proper rest position for both uppercase and lowercase.

Refer next to figure 9-36 Cam overthrow is a greater problem in returning to lowercase than in shifting to uppercase. As the cam returns to the lowercase position, the roller of the shift arm is rolling from the high point to the low point of the cam. The pressure of the roller against the receding surface tends to accelerate the movement of the cam. Excessive speed of the cam could cause a noisy operation and parts breakage. To prevent cam acceleration, a braking action is necessary. A shift arm brake made of heavy spring steel operates just in front of the shift cam. A nylon brakeshoe, attached to the end of the brake, rides a raised surface of the circumference of the cam. The friction applied by the brake prevents acceleration of the cam and causes the shift action to be the same for both uppercase and lowercase.

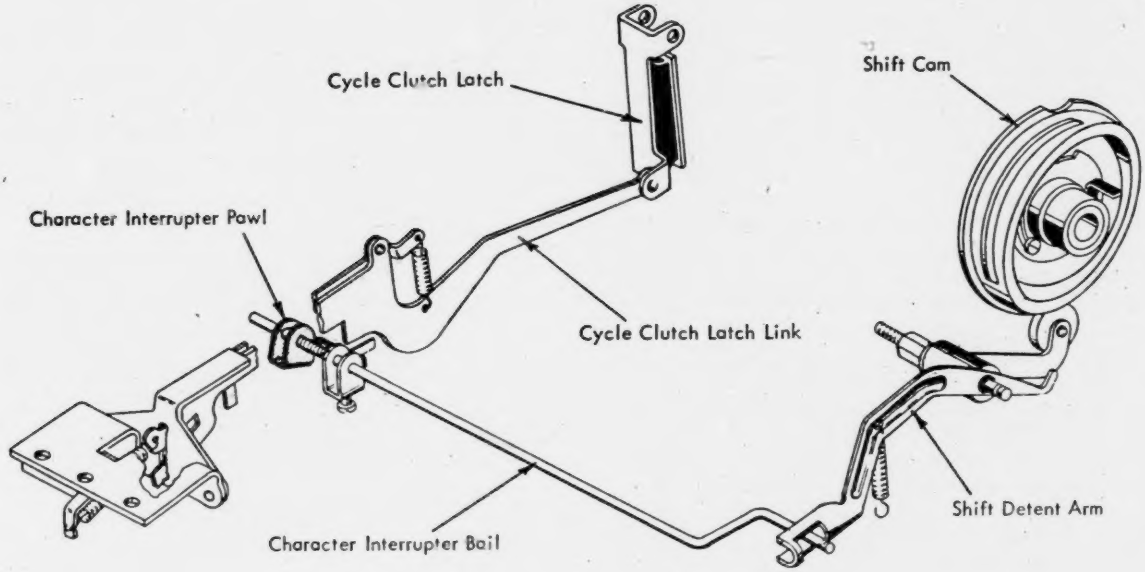
CHARACTER INTERRUPTER.—If the shift is already in process when a letter key is depressed, the character must be delayed until the shift is completed. Otherwise the shift would be interrupted in mid operation and an erroneous character would result. The character is delayed by blocking the cycle clutch release during a shift operation. When the shift cam starts an operation,



91.457
Figure 9-35.—Shift arm and detent.



91.458
Figure 9-36.—Shift cam brake.


Cycle Clutch Latch
Shift Cam
Character Interrupter Pawl
Cycle Clutch Latch Link
Shift Detent Arm
Character Interrupter Bail

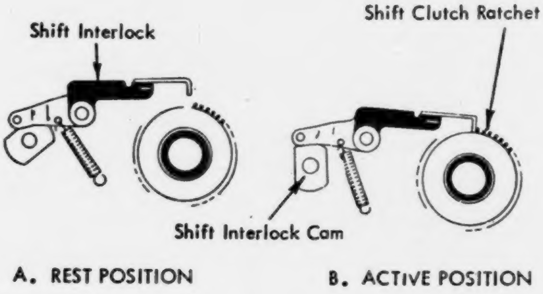
91.459

Figure 9-37.—Character interrupter.

the detent must move out of the recess in the cam. A forward extension of the detent lever operates a bail under the right side of the keyboard. A small pawl (character interrupter pawl), shown in figure 9-37 on the left end of the bail is rotated up into the path of the cycle clutch latch link. The pawl blocks the forward movement of the link and prevents the release of the cycle clutch.

This interlocking action does not prevent the depression of the keylever or the interposer. The interposer is merely latched down into storage. When the shift action is completed, the detent enters the recess in the cam. The bail is rotated back to the rest position and the pawl moves out of the path of the cycle clutch latch link. The cycle clutch latch link is then pulled forward by its extension spring and the stored character is printed. If the shift keylever and character keylever are depressed simultaneously, both operate for an instant until the filter shift has a chance to actuate the shift interlock. During that time, the character interrupter pawl collides with the bottom of the cycle clutch latch link. The character interrupter mechanism must yield in order to prevent parts damage. A torsion spring around the character interrupter bail loads the interrupter pawl against an adjustable stop on the bail. If a collision occurs, the interrupter pawl can yield by overcoming the torsion spring as the interrupter bail rotates.

SHIFT INTERLOCK.—Look at figure 9-38 Operating the shift mechanism when the type head is in the process of printing would result in parts damage. The rotate detent would be engaged in a notch of the type head and the type head would be against the platen. At this time


Shift Interlock
Shift Clutch Ratchet
Shift Interlock Cam
A. REST POSITION
B. ACTIVE POSITION

91.460

Figure 9-38.—Shift interlock.

no rotation of the type head can be allowed; therefore, the shift must be prevented from operating once the type head has started toward the platen.

We have seen that the shift spring clutch remains disengaged as long as the shift clutch ratchet is prevented from rotating. This is true because an interlock arm is operated by a cam on the right end of the filter shaft. The interlock engages the teeth of the shift clutch ratchet and prevents rotation of the ratchet. When the cycle mechanism is at rest, as shown in figure 9-38A, a roller on the interlock rests near the low point of the interlock cam, allowing free operation of the shift mechanism. As soon as a cycle operation begins, the filter shaft rotates, causing the interlock cam to move the interlock into the teeth of the shift clutch ratchet as in figure 9-38B. This interrupts the shift operation until the cycle operation is completed.

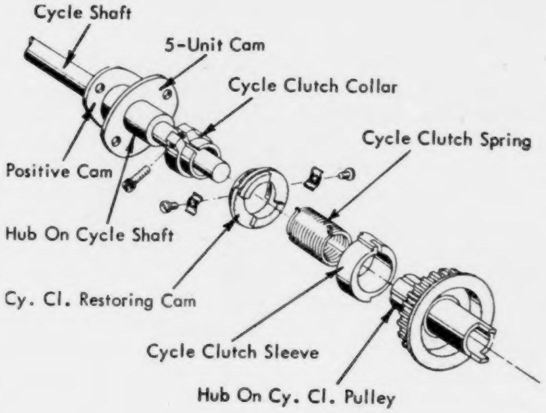
If an operator should operate the shift immediately after striking a character, the shift cam could begin to rotate before the filter shaft had sufficient time to actuate the shift interlock. This could cause an erroneous character to print, because the shift arm had already begun to move. This is known as beating the shift. This occurs mostly in shifting from uppercase to lowercase. Shifting from lowercase to uppercase is no problem because the shift arm does not rest against the cam in lowercase. The cam must rotate somewhat before it begins to move the shift arm, thereby allowing the filter shaft sufficient time to actuate the shift interlock.

To overcome the problem of beating the shift coming out of uppercase, a redsigned shaft cam has been incorporated in the Selectric. This redesigned cam has a longer uppercase dwell than the former style cam. The longer dwell allows the filter shaft sufficient time to operate the shift interlock before the shift arm begins to move, thus overcoming the problem. The new style shaft cam requires a different shift clutch ratchet, because the cam now rotates 220° going from uppercase to lowercase and 140° going from lowercase to uppercase. With this longer cam rotation when shifting from uppercase to lowercase, the detent notch in the cam (that operates the character interrupter) has been elongated by 40°. This elongation of the notch allows a character to come out of storage a short period of time before the shift operation has completed. This can be done without any ill effects, because under dynamic conditions there is a time delay between cycle clutch release and cycle shaft operation. Without early storage release (going to lowercase) the operator's typing rhythm could be affected.

CYCLE CLUTCH OPERATION

The cycle operation occurs each time a character prints. Everything concerned with printing a character on the paper is powered by the cycle shaft either directly or indirectly. The cycle shaft extends from the center of the machine out through the left sideframe. The left end of the shaft is supported by a self-aligning porous bronze bearing. The right end fits into the cycle clutch pulley hub in the center of the machine. A bronze sleeve inside the hub acts as a bearing for the cycle shaft.

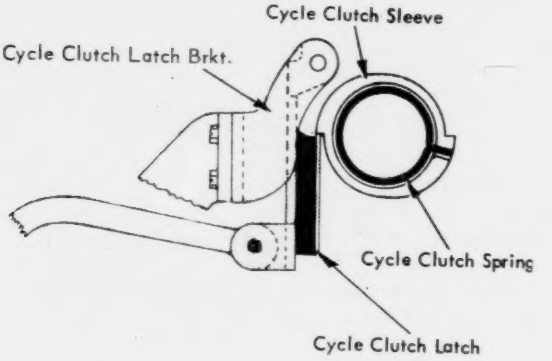
Look at figure 9-39. The cycle clutch pulley is in continuous rotation whenever the motor is running, but the cycle shaft operates only during a print operation. A spring clutch, called the cycle clutch spring, is the driving connection between the hub on the cycle clutch pulley and a hub on the cycle shaft. The cycle clutch spring engages and disengages the hub of the cycle clutch pulley. The cycle clutch spring operates exactly the same as the spring clutch in the shift mechanism. The left end of the cycle clutch spring fits around the hub on the cycle shaft and is clamped to this hub by the cycle clutch collar. The tip of the spring is turned



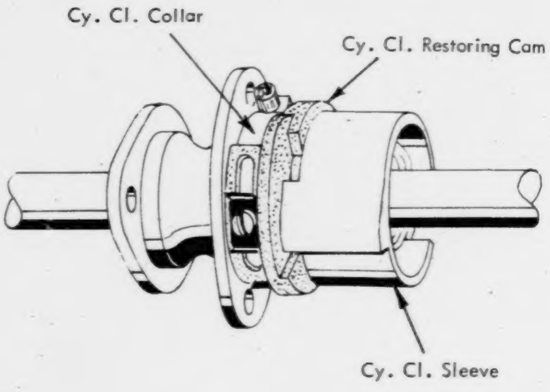
91.461
Figure 9-39.—Cycle clutch—exploded view.

up so as to fit into a slot in the collar. This arrangement prevents any slippage at the left end of the spring clutch and makes it possible to adjust the position of the spring in relation to the shaft. (The collar does exactly the same job as the spring clutch retaining plate on the shift cam.) The right end of the cycle clutch spring encircles a hub on the cycle clutch pulley. (The hub on the cycle clutch pulley functions the same as the shift clutch arbor on the shift mechanism.)

The inside diameter of the cycle clutch spring is slightly less than the diameter of the hub on the cycle clutch pulley so that the spring clutch tightens when the hub rotates. The right-hand tip of the spring clutch projects into a notch in the cycle clutch sleeve. The sleeve fits loosely around, inclosing the spring clutch and acts as a control for the right end of the cycle clutch spring. (The sleeve performs the same function as the shift clutch ratchet.) The cycle clutch sleeve has two steps on its exterior surface 180° apart. As the cycle clutch is driving the cycle shaft one of the steps on the clutch sleeve contacts a vertical latch that is placed in the path of the sleeve, as shown in figure 9-40. This latch, called the cycle clutch latch, stops the rotation of the clutch sleeve, thereby stopping the right end of the cycle clutch spring. (The sleeve and latch operate the same as the shift clutch ratchet and shift release arm.) The left end of the cycle, clutch spring rotates farther after the right end is stopped because of the momentum built up in the cycle shaft, filter shaft, and print shaft. This additional rotation given to the left end of the cycle clutch spring is in the unwinding direction and causes the spring to expand about the hub on the cycle clutch pulley. This unwinding breaks the driving connection between the hub and the spring.



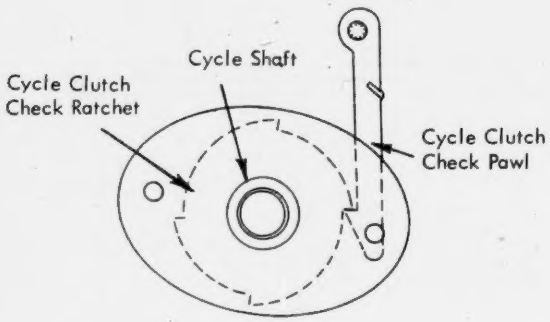
91.462
Figure 9-40.—Cycle clutch—side view.



91.463
Figure 9-41.—Cycle clutch stop.

Next, refer to figure 9-41. Since the shaft tends to travel beyond its rest position due to momentum, an overthrow stop is required. Two lugs on the side of the nylon cycle clutch restoring cam project into notches in the left side of the cycle clutch sleeve and operate as an overthrow stop. When the sleeve is stopped by its latch, the cycle shaft continues to rotate under momentum (expanding the cycle clutch spring) until the nylon stop contacts the lugs on the sleeve, stopping the overthrow of the shaft. The shock of stopping the overthrow of the cycle shaft tends to bounce the cycle shaft backwards. To prevent this from occurring a check pawl drops into a notch in a check ratchet, located on the left end of the cycle shaft shown in figure 9-42. The pawl drops in when the clutch is disengaged. (It performs the same function as the shift detent roller.)

Both the overthrow stop and the cycle shaft return exactly to their rest position at the completion of each cycle operation. (The cycle shaft is in its rest position when the positive selector cams are on their low dwells and the working face of a notch on the check ratchet is against the working face of the check pawl.) The shock of stopping the overthrow of the cycle shaft, filter shaft, and print shaft is transmitted from the cycle shaft through the collar, the overthrow stop, the sleeve, and to the cycle



91.464
Figure 9-42.—Cycle clutch check pawl.

clutch latch. This is why the cycle clutch latch has vulcanized rubber mounting designed to absorb shock.

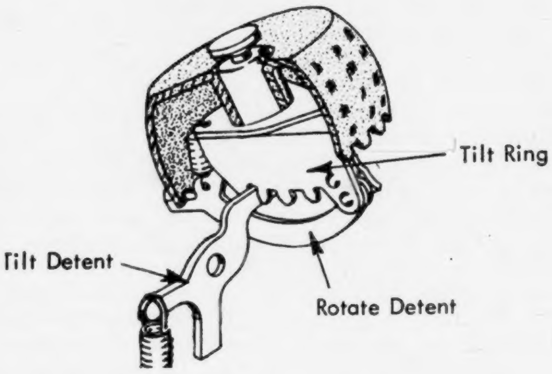
Shock also occurs in the shift mechanism. The shock of stopping the momentum of the shift cam is transmitted from the shift cam through the overthrow stop the lug on the ratchet, and to the shift release arm. The release arm is shaped like a horseshoe so that it can absorb this shock. The cycle clutch is allowed to engage by pivoting the cycle clutch latch forward out of the path of the step on the clutch sleeve. The clutch spring then quickly decreases in diameter because of its own spring tension. The rotating clutch pulley hub tightens the spring and drives the cycle shaft. The entire clutch assembly rotates through 180°. The second step of the clutch sleeve then contacts the cycle clutch latch which has been moved to the rear into its path. This causes the cycle clutch to be disengaged again as previously described.

ALIGNMENT

Alignment is the process of positioning the type head both horizontally and vertically to an exact printing point. This cannot be done by simply rotating and tilting the type head because of tolerances, inertia, momentum, elasticity of the system, changing spring loads, and many other factors. All these factors cause the alignment of the type head to vary in a haphazard way. Any variation in alignment of the type head directly affects the print quality of the machine. Alignment variation is undesirable and must be eliminated. The same method is used to eliminate alignment variations in both the tilt and rotate mechanism. Since the tilt mechanism operates basically the same as the rotate mechanism and is simpler in structure, most of the alignment concepts will be discussed in the tilt mechanism. You must have a good understanding of these concepts in order to properly diagnose and alignment problem.

TILT ALIGNMENT. — To insure that any character in one of the four bands of characters on the type head is properly aligned vertically when the type head prints, the tilt ring must be tilted to an exact position and locked. As previously mentioned, the tilt ring cannot be accurately positioned by its mechanism alone because of uncontrollable factors. To overcome this condition, the tilt mechanism can refine and lock the tilt ring in the exact position desired, after the tilt mechanism coarsely positions the tilt ring. This is done by placing a specific amount of play in the tilt ring and using a detenting mechanism to refine and lock the tilt ring into position. This built-in play is located in the tilt pulley link on the gearless tilt and is commonly referred to as "tilt ring play."

If the tilt mechanism tends to supply too much or too little motion to the tilt ring for a given tilt selection, the detenting mechanism corrects this error by utilizing the tilt ring play. The left side of the tilt ring contains four V-shaped notches, illustrated in figure 9-43, that correspond to the four tilt positions. A small arm called the tilt detent, mounts in a slot on the left side of the yoke and operates in



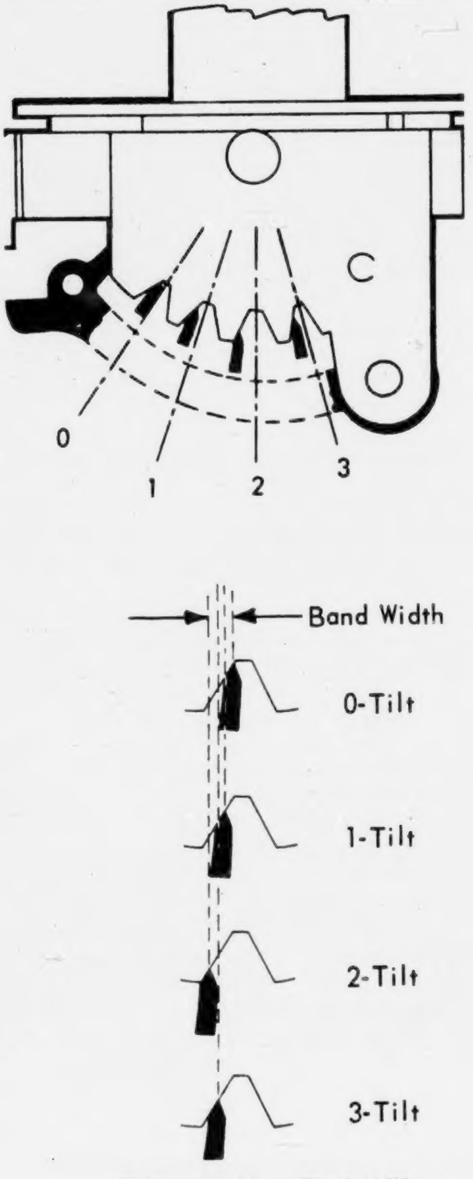
91.465
Figure 9-43.—Tilt ring detenting.

the notches on the tilt ring. When the tilt ring is moved to approximately the correct tilt position, the tilt detent is allowed to enter one of the notches in the tilt ring. A heavy extension spring causes the detent to seat in the V-shaped notch, thus camming the tilt ring into, and locking it on, an exact-print position. It is the built-in "tilt ring play" that enables the tilt detent to cam the tilt ring into the proper tilt position.

Since the tilt detent puts the tilt ring in the exact position, the tilt mechanism only has to coarse align the tilt ring (to each tilt position when selected) so that the tilt detent can enter and bottom in the correct notch without using all the tilt ring play. This means that the largest coarse alignment variation between any two of the four tilt positions must not exceed the tilt ring play, or a detenting failure will result.

To insure that detenting failure will not occur after a certain amount of wear comes into the tilt mechanism, the amount of coarse alignment variation must be within a specific tolerance. The tilt mechanism should be set so that the "bandwidth" of the tilt mechanism is within this tolerance. Bandwidth in the tilt mechanism is defined as the maximum difference between the relative position of the tilt detent in any two notches for all coarse tilt positions (fig. 9-44). Of all the factors that affect the tilt ring position, only one, the accuracy of adjustments, can be controlled by the office machine repairman. The more accurate the adjustments, the less variation there is in the tilt ring position for the different characters and the narrower the bandwidth. It is not necessary to achieve a bandwidth any smaller than the given set up tolerance.

The procedure for observing coarse alignment in each tilt position is not complicated. With the power on half-cycle the machine. Place the Hooverometer (selectric type alignment gage) handle in position, as shown in figure 9-45. This handle will block the cycle clutch sleeve, now strike the keylever. After the machine has half cycled turn the machine off and make sure the cycle shaft is resting in a half-cycled position. To check, observe the position of the check pawl in the cycle shaft check ratchet. The check pawl should be detented in the half-cycle notch on the check ratchet, as shown in figure 9-46. Half-cycling is done under power so as to include all the stresses on the system.

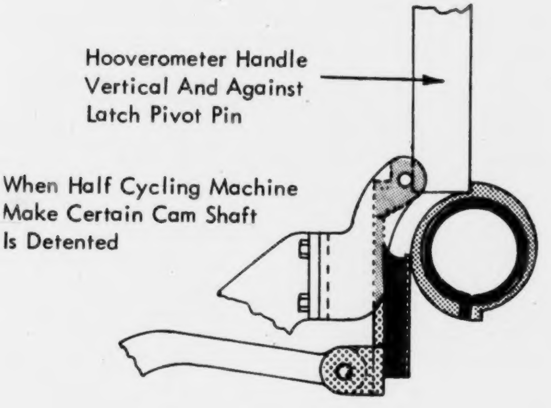


91.466

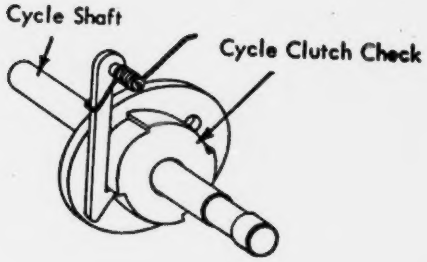
Figure 9-44. — Bandwidth.

Manually withdraw the detent and remove the tilt ring play in the negative direction by pressing lightly on the rear of the tilt ring. Allow the detent to re-enter the tilt ring notch while observing the point where the detent first contacts the side of the V-shaped notch.

Perform this check for each tilt position to visually measure how much coarse alignment variation there is in the system, and also which adjustment (or adjustments) is causing the variation. Each adjustment in the system affects coarse alignment in a different manner and shows

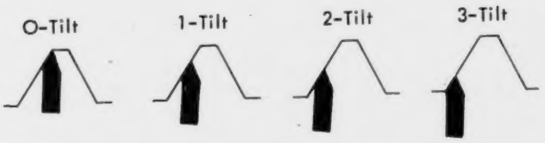

Hooverometer Handle Vertical And Against Latch Pivot Pin
When Half Cycling Machine Make Certain Cam Shaft Is Detented

91.467
Figure 9-45.—Half-cycling operation.


Cycle Shaft
Cycle Clutch Check

91.468
Figure 9-46.—Half-cycle operation.

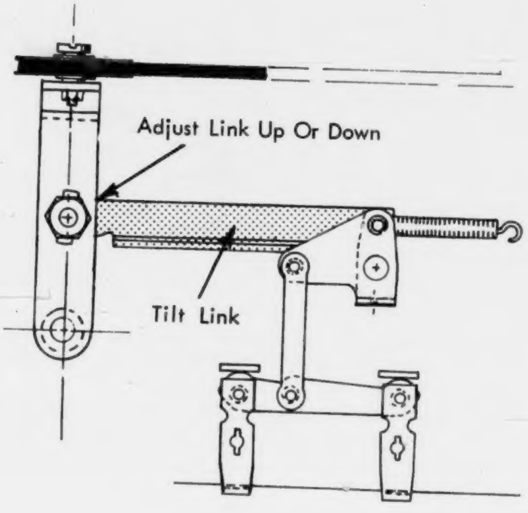
up in a definite pattern. By observing the pattern, you can easily diagnose a maladjustment in the system. Figure 9-47 illustrates a coarse alignment check of the four tilt positions. Note that there is a progressive loss of motion to the tilt ring from a tilt 0 to a tilt 3. This indicates that the tilt arm is receiving equal increments of motion from the tilt differential system but is not multiplying the motion properly. The part you adjust for this discrepancy is shown in figure 9-48. Moving the tilt link down in the elongated slot on the tilt arm will produce more motion by the tilt differential system.


O-Tilt
1-Tilt
2-Tilt
3-Tilt

91.469
Figure 9-47.—Course alignment check.

Alignment can be separated into two stages: coarse alignment and fine alignment. Coarse alignment is the introduction of the detent into the wide portion of the detent notch. Fine alignment occurs after the detent moves up into the seats in the notch. Once the tilt detent has fully seated in the tilt ring notch, any vertical misalignment problems cannot be attributed to coarse alignment adjustments. The problem lies in the carrier and rocker area and usually is caused by one of the following: too much upper ball socket play, side play in the tilt detent, vertical play in the rear carrier shoe, tilt ring side play, loose type head latch, improper detent timing, or worn rocker shaft bearings. Any of these conditions can cause poor vertical alignment.

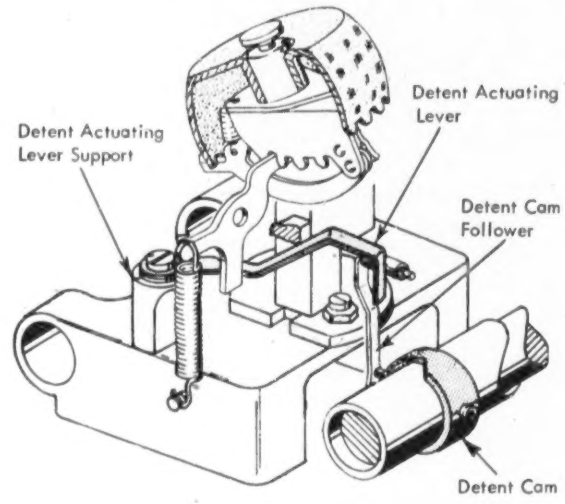
ROTATE ALIGNMENT.—Since the rotate mechanism must position the type head to eleven


Adjust Link Up Or Down
Tilt Link

91.470
Figure 9-48.—Tilt differential.

positions, it is a great deal more complex than the tilt mechanism. The alignment concepts brought out under the tilt mechanism also apply to the rotate mechanism, however, regardless of its complexity. Like the tilt ring, the type head is also coarse aligned to approximately the correct position (which is within the allowable bandwidth), and then a detent locks it into the exact position. Built-in play of the type head allows the rotate detent to refine the selected type head position after the head has been coarse aligned. This play comes from backlash between the slots in the ball joint and the pins in the upper and lower ball sockets. The rotate detent mounts on the tilt ring and operates in V-shaped notches cut into the skirt of the type head. It is spring-loaded at the rear into engagement with the type head. As in the tilt mechanism, once the rotate detent has fully seated in the type head notch, any horizontal misalignment problems cannot be attributed to coarse alignment adjustments. The problem lies in the carrier and rocker area and usually is caused by one of the following: side play in the rotate detent, improper detent timing, excessive side play of the rocker, binding in the rear carrier shoe, or anything that restricts the carrier from escaping properly.

DETENTING. — The type head cannot be tilted or rotated with the detents engaged. They must be held out of engagement until the type head has been completely positioned. They must also be removed from engagement before the type head can be restored to the rest position. The rotate detent operates under spring tension against the tilt detent. Refer to figure 9-49. As long as the tilt detent is not allowed to rise, the rotate detent cannot enter the notches of the type head. The tilt detent is controlled by a smaller lever called the detent actuating lever, located under the left side of the yoke. The lever pivots at the rear and extends forward along the right side of a lower extension of the tilt detent. When the detent actuating lever is operated to the left, the tilt detent moves down, pushing the rotate detent down with it. When the actuating lever moves to the right, both detents are allowed to rise. Movement of the detent actuating lever is controlled by the detent cam through the detent cam follower.

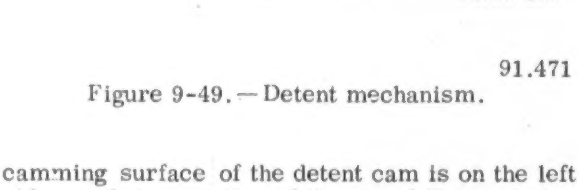


91.471

Figure 9-49. — Detent mechanism.

The cam follower is pivoted on a bracket below and to the rear of the print sleeve and extends up alongside the detent cam in position to operate the detent actuating lever. The camming surface of the detent cam is on the left side so that operation of the cam follower is toward the left against the detent actuating lever. The rotate detent does not pivot into engagement as the tilt detent does. It contains an elongated hole at the front, as illustrated in figure 9-50 which allows both the front and the rear of the detent to move up and down. A small flat link at the top stabilizes the detent. If the rotate detent were pivoted at the front, the amount of travel and timing of the detent would vary with the tilt selection. With the sliding arrangement, the rotate detent action is approximately the same for all tilt selections.

While the type head is being positioned, the cam follower is against the high part of the detent cam. This holds the detent actuating lever



91.472

Figure 9-50. — Rotate detent.

to the left to prevent the detents from engaging their notches. During the positioning of the type head, the detent cam is rotating, but it maintains the same high point for the cam follower. As soon as the rotate and tilt operations have been completed, the cam follower moves to the right into a recess in the detent cam. This allows the detent actuating lever to move to the right to permit operation of the tilt and rotate detents. As the type head is being moved toward the platen, the detent cam continues to turn, but it maintains the same low point for the follower.

As soon as the character has printed, locking the type head in position is no longer necessary; therefore, the detents can be disengaged to allow the type head to restore to the rest position. As the rocker is restoring to the rest position, the detent cam moves the cam follower back to the left onto the high part of the cam. This action causes the detent actuating lever to disengage the detents from their notches. Timing of the detenting is such that both detents begin to engage their notches just as the type head completes its positioning and are disengaged just as the type head starts to rotate and/or tilt back to the rest position.

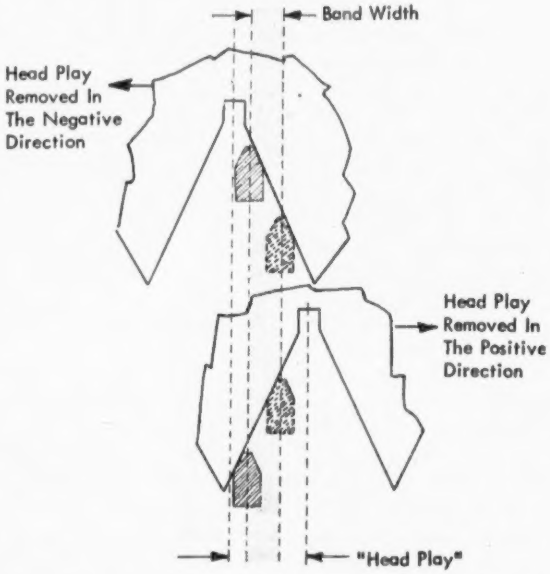
DETENT TIMING.—The timing of the print shaft with respect to the cycle shaft controls the timing of the detent. Detent timing must be set accurately in order to prevent damage from occurring in the tape system or the type head. If the rotate detent is allowed to engage the type head too soon, it may enter the wrong detent notch. If this occurred during a negative rotation of the type head, the rotate tape would tend to slacken and jump off its pulleys. This could lead to tape breakage.

If the detent is allowed to engage the type head too soon during a positive rotation, tape or type head breakage may result due to the continued pull on the tape. Also, retarding the detent timing may lead to breakage, because the detent remains in the type head notch when the head is trying to restore. Detent timing can also affect print alignment. It is possible for the detents to begin to withdraw before the type head prints. For this reason, the detent timing should be adjusted as late as possible without restricting the type head from restoring. Several factors affect detent timing. Some of the most important are: the adjustments of the rotate and tilt systems, type head homing, detent actuating lever and cam adjustments, and timing of the print shaft relative to the cycle shaft. If any of these are changed, the machine must always be cycled by hand to check the detenting action before it is operated under power. It should be noted that the detents are spring-loaded into engagement, but they are driven out of engagement by the cam. This is to prevent parts breakage should the type head not be properly positioned when the detents try to engage.

WEAR POTENTIAL.—Wear potential in the tilt and rotate mechanism is defined as the ability of the tilt and rotate mechanisms to properly coarse align the type head after a measurable amount of wear is felt in either mechanism. Although wear potential is designed into both mechanisms, it will only be discussed in the rotate mechanism. A portion of the type head play provides the rotate system with a substantial amount of wear potential. In order to explain how this is done, we must first discuss the relationship between type head play, type head homing, and bandwidth.

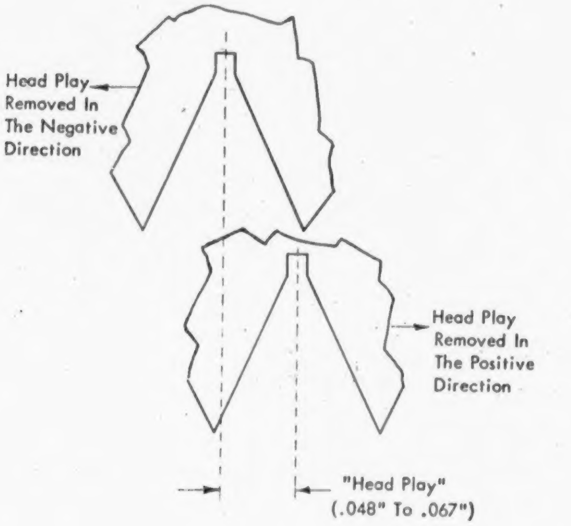
Figure 9-51 illustrates the type head play by showing a single detent notch (of the type head) in the two positions as allowed by the built-in play. The type head play, which is approximately .060" measured at the type head skirt, can be separated into three sections or segments, each having its own function.

The first segment of head play is for detent timing purposes by the type head homing adjustment. Look at figure 9-52. The typing element

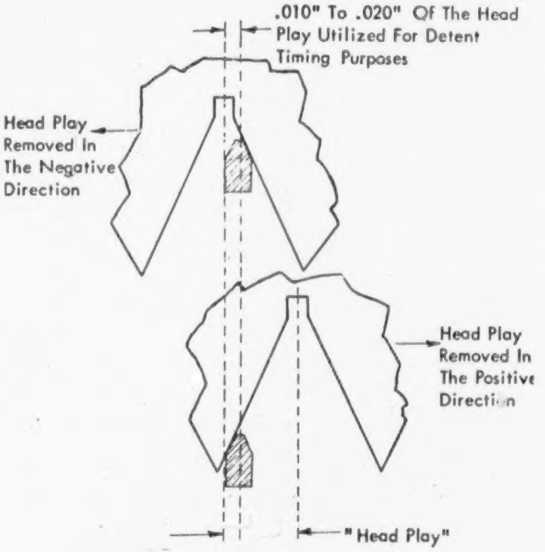

Band Width
Head Play Removed In The Negative Direction
Head Play Removed In The Positive Direction
"Head Play"

91.473

Figure 9-51.—Typehead play.


Head Play Removed In The Negative Direction
Head Play Removed In The Positive Direction
"Head Play" (.048" To .067")

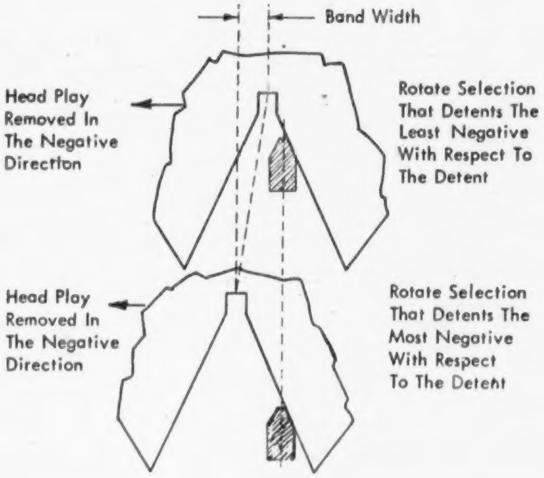
91.474
Figure 9-52.—Typehead homing.


.010" To .020" Of The Head Play Utilized For Detent Timing Purposes
Head Play Removed In The Negative Direction
Head Play Removed In The Positive Direction
"Head Play"

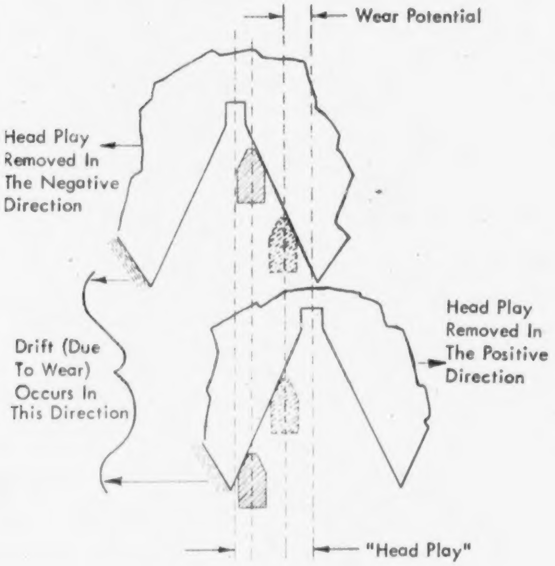
91.475
Figure 9-53.—Bandwidth.

is "homed" to the rotate selection that coarse aligns the most positive (with respect to the rotated detent) when the head play is removed in the negative direction. It is "homed" so that this rotate selection aligns .010" to .020" on the negative side of the detent notch when the head play is removed in the negative direction. The purpose of this adjustment is to slightly retard the restoring of the type head whenever it restores in the positive direction so that the rotate detent can begin to withdraw before the type head starts to restore. If the withdrawal of the detent did not lead the restoring of the type head, the detent would restrict the head from restoring, causing breakage in the system. This homing adjustment uses up approximately one-fourth of the type head play.

The second segment of head play is bandwidth. With head play removed in the negative direction, figure 9-53 illustrates bandwidth by showing the amount of variation (in coarse alignment) between the rotate selection that aligns the least negative and the rotate selection that aligns the most negative with respect to the rotate detent. Figure 9-54 illustrates bandwidth in relation to head play. The allowable bandwidth of the rotate system may utilize as much as one-half of the type head play. Note that almost


Band Width
Head Play Removed In The Negative Direction
Rotate Selection That Detents The Least Negative With Respect To The Detent
Head Play Removed In The Negative Direction
Rotate Selection That Detents The Most Negative With Respect To The Detent

91.476
Figure 9-54.—Bandwidth.

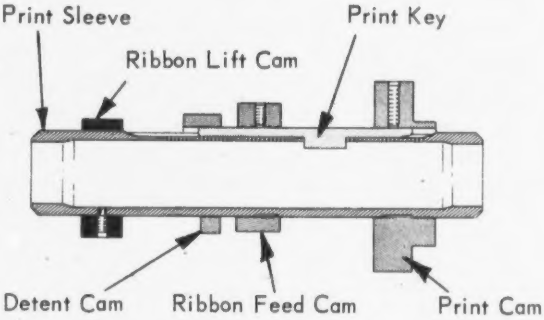

Wear Potential
Head Play Removed In The Negative Direction
Drift (Due To Wear) Occurs In This Direction
Head Play Removed In The Positive Direction
"Head Play"

91.477
Figure 9-55.—Wear potential.

three-fourths of the head play is for type head homing and bandwidth.

The remaining head play is used for wear potential. Look at figure 9-55. When wear occurs in the system, the type head drifts in the negative direction with respect to the detent. This also causes the head play and bandwidth to drift in the negative direction with respect to the detent. As long as this drift does not exceed the wear potential portion of the head play, the detent continues to fine-align the type head. Once it has exceeded the wear potential, the rotate selection that coarse—aligns the most negative with respect to the detent fails to seat in the detent notch. The detent then fails to seat, causing that character to print out of alignment.

PRINT SHAFT AND PRINT SLEEVE.—The print shaft extends between the sideframes just to the rear of the keylever fulcrum rod. It is supported at each end by a self-aligning porous bronze bearing. A small gear outside the left sideframe connects the shaft, through idler gears, to the cycle shaft gear. The ratio between the two gears is 2:1. This means that each time the cycle shaft completes a cycle operation (180° rotation), the print shaft is rotated 360° (one complete revolution). The print sleeve of the carrier assembly rides on the print shaft. A keyway throughout the length of the print shaft provides a rotary connection between the sleeve and the shaft, yet permits a lateral movement of the carrier.



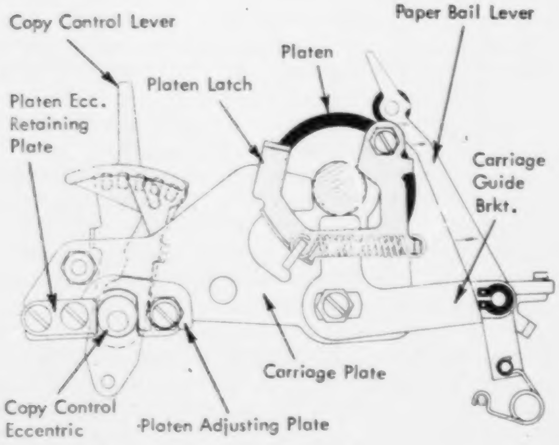
91.478
Figure 9-56.—Print sleeve and cams.

A key fits through a hole in the print sleeve and into the keyway of the print shaft, as illustrated in figure 9-56. Whenever the print shaft is rotated, the print sleeve is rotated by the key connection. The print sleeve contains four cams. The two middle cams are the ribbon feed cam and the detent cam for the type head alignment. Both of these cams are keyed to the print sleeve by the same key that extends into the print shaft. Each cam is secured to the sleeve by setscrews. The cam at the left is the ribbon lift cam. It is setscrewed to the print sleeve, causing the cam to rotate with the sleeve. The setscrew mounting also prevents the print sleeve from shifting toward the left.

The cam at the right is a double cam called the print cam. Its function is to power the type head toward the platen and restore it to rest. Two camming surfaces are necessary for this operation. The smaller surface to the right, called the print cam, moves the type head to the platen. The larger cam surface, called the restoring cam, restores the type head and prevents it from rebounding. The print cam is also keyed to the print sleeve to rotate with the sleeve. The print cam is held in position by two setscrews to prevent the print sleeve from moving to the right and to provide a solid driving connection between the sleeve and the cam.

PLATEN.—The purpose of the platen is to feed the paper vertically and to provide a solid backing for the paper during a typing operation. The quality of type impression obtained is determined to a large extent by the condition of the platen. Platen rubber may be adversely affected by numerous factors, such as light, heat, chemicals, etc. An old or worn platen may be considerably harder than a new platen and may also vary slightly in diameter. The IBM Selectric Typewriter is equipped with a platen with a hardness density comparable to the number 2 platen used with the standard IBM electric typewriter. The platen is held in position on the machine by a latch pivoted at the front on each carriage plate. Now let's look at figure 9-57. The platen may be removed by pressing the rear of the latches down and lifting the platen out. It may be installed by snapping it into position without depressing the latches. The camming action of the latches causes them to remove all vertical as well as horizontal play from the platen.

COPY CONTROL.—Still referring to figure 9-57, we see that the purpose of the copy control mechanism is to position the platen forward or backward for different thickness of typing material. Positioning the platen maintains the correct relationship between the anvil and the point of impact of the type head with the paper. The copy control is operated by the copy control lever, located at the left end of the carriage. The lever is attached to the copy control shaft that extends out through the sides of the powerframe. An eccentric collar at each end of the shaft operates between adjusting parts attached to the carriage ends. When the lever is moved to the rear the shaft rotates, causing the eccentric collars to contact the platen eccentric retaining plates. This action forces the carriage ends to the rear. The platen and entire paper feed mechanism move with the carriage. When the copy control lever is pulled forward, the eccentric collars contact the platen adjusting plates and force the carriage forward into the normal position. The copy control lever can be set in five different positions. A spring detent attached to the powerframe acts against a knob on the copy control lever to hold it in place.



91.479

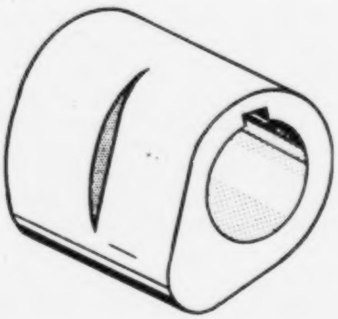
Figure 9-57.—Copy control mechanism.

PRINT MECHANISM

The print mechanism contains an operator impression control lever which permits the operator to regulate the impression for any desired application. The operator may change the overall impression of the type head by merely positioning the impression control lever to one of five settings. In addition, the print mechanism is equipped with an automatic velocity selection mechanism. The purpose of this mechanism is to provide a lighter impression for the period, comma, colon, semicolon, quotation mark, apostrophe, hyphen, and underscore, regardless of where the impression control lever may be set. Before going into any detail on the impression control mechanism, it is necessary to first understand how the automatic velocity selection mechanism operates, since the two mechanisms are directly related.

AUTOMATIC VELOCITY SELECTION (DUAL CAM).—Caution: The following material uses the terms low velocity lobe and low velocity cam; two separate cams.

The printing operation of all the uppercase and lowercase characters in positions 32, 36, 38, 39, and 42 produces a lighter impression on the typed copy than in any of the other positions. The purpose of this is to improve the general appearance of the typed copy by producing a more uniform impression between all characters, large and small. This is done by using a print cam that has two different camming surfaces. Look at figure 9-58. The low and high points of both camming surfaces are identical. The only difference is in the contour (profile) between their low and high points. The contour of one camming surface provides the type head

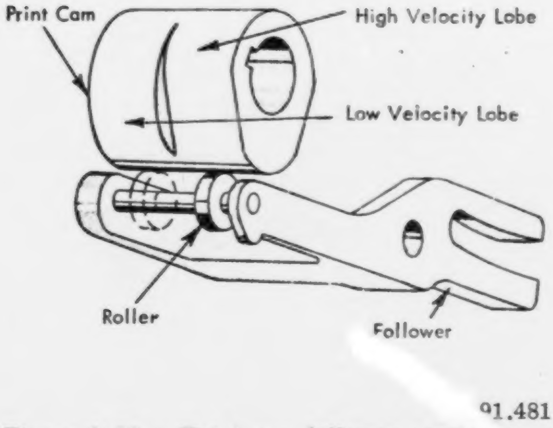


91.480
Figure 9-58.—Print cam (dual velocity).

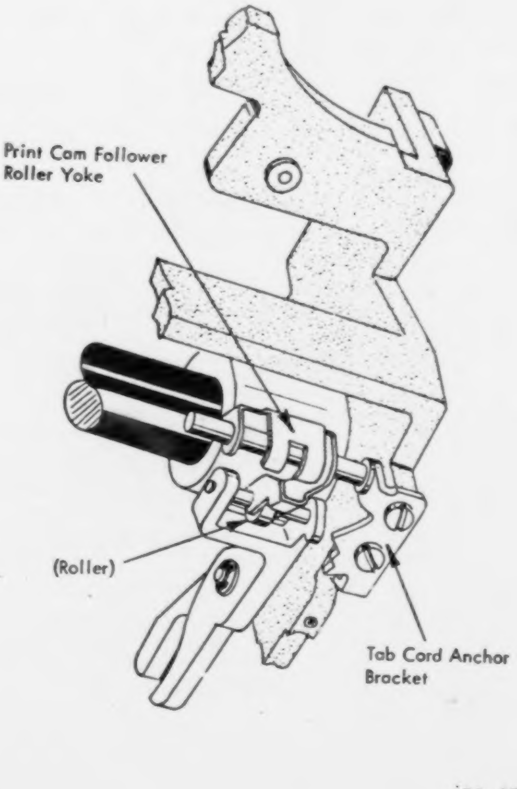
with a lower impact velocity than the other. Thus, a lighter impression is produced when this camming surface is used. The difference in type head velocities produced by the two camming surfaces remains proportional, regardless of the impression control lever setting. In figure 9-59 we see the selection mechanism positions of the print cam follower roller under the proper camming surface of the dual velocity print cam whenever a character is selected at the keyboard.

The print cam follower assembly is mounted on a pivot pin, located in the right side of the carrier below and to the rear of the print cam.

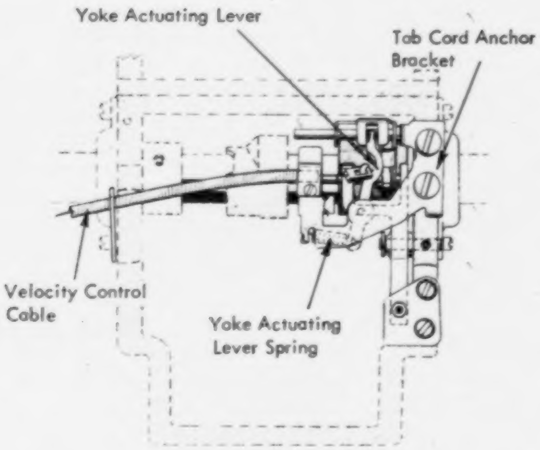
The roller mounts on a pin on the print cam follower and is free to slide left or right on this pin. The camming surface or lobe on the print cam that produces the greatest impact velocity is called the high velocity lobe. This is the right-hand lobe on the print cam. The left-hand lobe (producing less impact velocity) is called the low velocity lobe. Figure 9-60 shows that the roller is positioned (left or right) under either camming surface of the print cam by the print cam follower roller yoke, which straddles the roller. The yoke is mounted on a pin that protrudes from the tab cord anchor bracket assembly. The yoke is also free to slide left or right on its mounting pin. Look at figure 9-61 and you will see that a lever, which controls the lateral position of the yoke and roller, mounts on the tab cord anchor bracket by a shouldered rivet. This lever is called the yoke actuating lever. The yoke actuating lever is spring-loaded at the rear in a clockwise direction (observed from the bottom of the machine) by the yoke actuating lever spring. This spring tension positions the roller directly beneath the



91.481
Figure 9-59.—Print cam follower assen

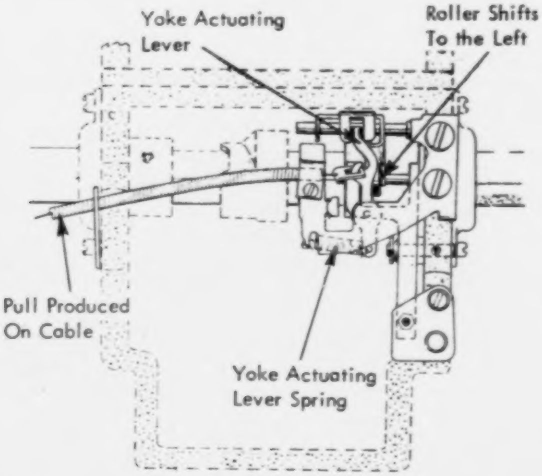


91.482
Figure 9-60.—Print cam follower roller yoke.


Yoke Actuating Lever
Tab Cord Anchor Bracket
Velocity Control Cable
Yoke Actuating Lever Spring

91.483
Figure 9-61.—Yoke actuating lever and spring.

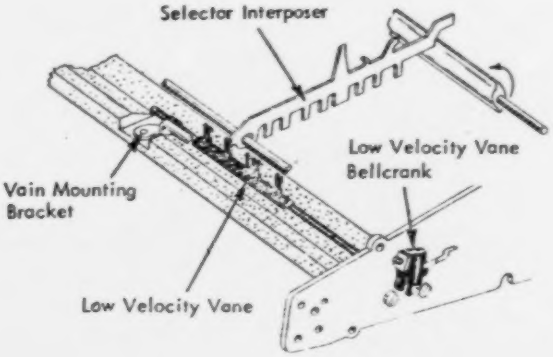
high velocity lobe of the print cam, as shown in figure 9-61. A sheathed cable called the velocity control cable fastens to a hook portion of the yoke actuating lever. Whenever the velocity control cable is pulled the yoke actuating lever rotates counterclockwise (stretching its spring), shifting the print cam follower roller from the high velocity lobe to the low velocity lobe of the print cam, as shown in figure 9-62.


Yoke Actuating Lever
Roller Shifts To the Left
Pull Produced On Cable
Yoke Actuating Lever Spring

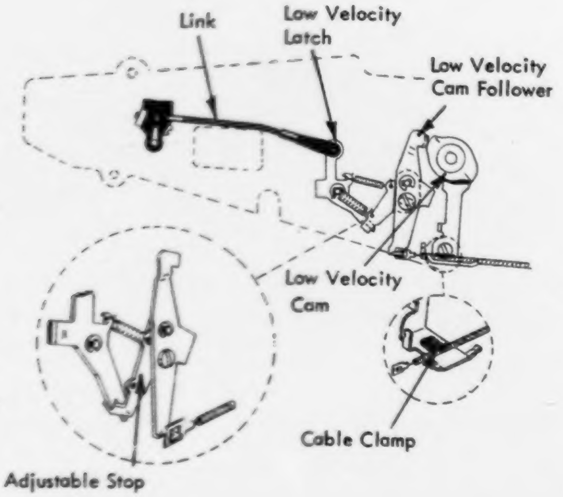
91.484
Figure 9-62.—Low velocity operation.

Refer back to figure 9-61. When the pull on the velocity control cable is relaxed, the yoke actuating lever spring shifts the roller back to the right, positioning it under the high velocity lobe of the print cam. Whenever a low velocity character is selected (at the keyboard), a pull on the velocity control cable shifts the roller to the low velocity lobe on the print cam. This pull on the cable is initiated at the keyboard. When any one of the selector interposers in positions 32, 36, 38, 39, or 42 are powered forward by the filter shaft, a knob on the forward end of the interposer contacts an upright lug on the low velocity vane, causing it to rotate forward. This is illustrated in figure 9-63. The left end of the low velocity vane pivots in a mounting bracket fastened to the top surface of the front keylever guide comb support. The right end of the vane pivots in a hole in the right-hand keyboard sideframe. (The vane extends only halfway across the keyboard.) The lateral position of the vane is controlled by a C-clip located on each side of the vane mounting bracket. The low velocity vane bellcrank is fastened to the right end of the vane outside the keyboard sideframe. Rotation of the vane and bellcrank, during a low velocity operation, creates a pull on the link, causing the low velocity latch to rotate counterclockwise about its mounting stud. The rotation of the latch swings it out of the operating path of an adjustable stop on the low velocity cam follower.

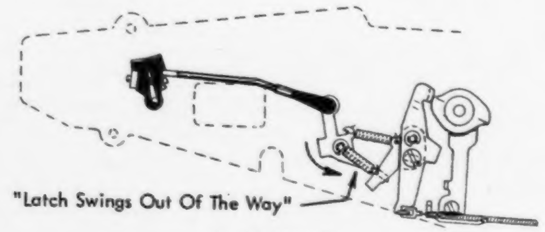
The cam follower and the adjustable stop operate as one piece pivoting about a stud on the keyboard sideframe shown in figure 9-64. A heavy spring, hooked to the adjustable stop


Selector Interposer
Low Velocity Vane Bellcrank
Vain Mounting Bracket
Low Velocity Vane

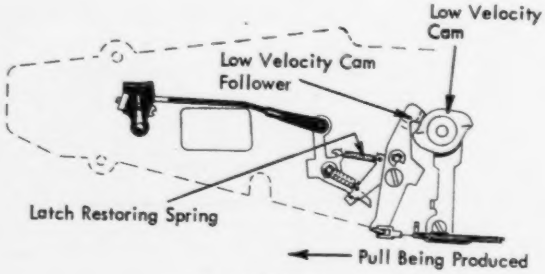
91.485
Figure 9-63.—Low velocity selection.



91.486
Figure 9-64.—Machine at rest.



A. BEGINNING



B. OPERATION.

91.487
Figure 9-65.—Low velocity operation.

and anchored to the latch mounting stud, spring-loads the follower in a clockwise direction. The velocity control cable is hooked to the lower extension of the follower. The upper extension of the follower is spring-loaded against the low velocity cam, which is a double-lobed cam setscrewed to the right end of the filter shaft directly to the left of the shift interlock cam. The radial position of the cam is set so that the cam follower is on the high part of one of the cam lobes when the filter shaft is at rest.

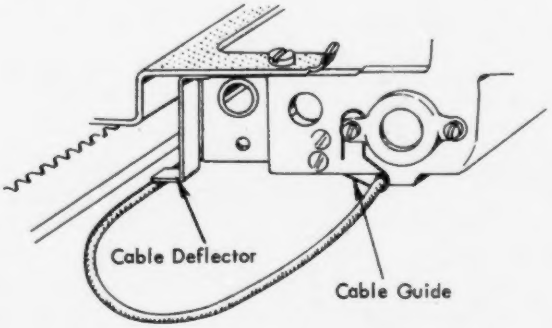
Whenever the follower is allowed to follow the contour of the cam toward its low point, a pull is produced on the velocity control cable by the heavy spring load on the follower. The cam follower begins to follow the contour of the cam toward its low point whenever the low velocity latch is rotated out of the path of the adjustable stop as shown in figure 9-65A. This occurs each time a low impression character is selected at the keyboard. Figure 9-65 shows the low velocity cam follower riding down toward the low dwell of the low velocity cam, thereby causing a pull on the velocity control cable. Note that the low velocity latch is attempting to restore back to its rest position but cannot fully restore until the cam follower is powered back to its rest position. The latch restoring spring between the latch and the adjustable stop provides the restoring action not only for the latch but for the low velocity vane also. As the low velocity print operation is completing the follower restores back to the high part of one of the cam lobes on the low velocity cam. This relaxes the pull on the velocity control cable so that the yoke actuating lever spring, which is shown back in figure 9-62, shifts the print cam follower roller back to the right under the high velocity lobe of the print cam.

If a high velocity character is selected at the keyboard, the low velocity latch remains at rest in the operating path of the stop on the cam follower. The cam follower is restricted from following the contour of the cam toward its low point; therefore, no pull is felt on the velocity control cable. The print cam follower roller remains to the right under the high velocity lobe of the print cam, and a high velocity print operation results.

To prevent the print cam from interfering with the print cam follower roller as it shifts from one cam lobe to the other during a velocity selection operation, the print cam follower and roller is held disengaged from the print cam until the roller has shifted. This is done by an adjustable stop screw, located directly under the rear portion of the print cam follower shown in figure 9-66. The stop screw disengages the roller from the print cam as the cam approaches its rest position. The shifting of the roller occurs at the beginning and at the end of a low velocity print cycle, which is just when the print cam is leaving or approaching its rest position.

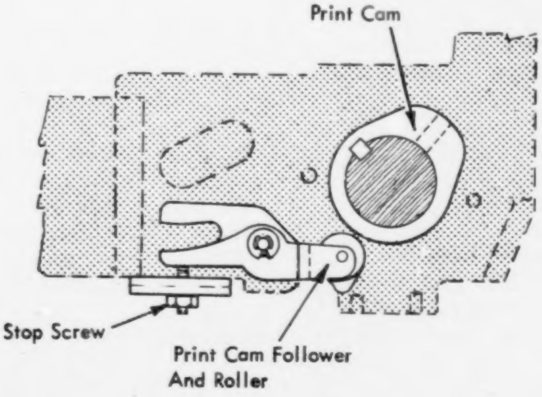
The velocity control cable consists of a thin strand of wire (with eyelets at each end) running through the center of a flexible plastic-coated sheath. The wire slides freely within the sheath, transmitting motion from the low velocity cam follower to the yoke actuating lever on the carrier. Both ends of the cable sheath are clamped rigidly to their respective mechanisms by cable clamps, which are shown in figures 9-64 and 9-65. Clamping the ends of the sheath allows the velocity control cable to operate efficiently as a motion transmitting device.

The velocity control cable passes through a wire guide located on the left side of the carrier, as shown in figure 9-67. The guide retains the cable against the underside of the carrier so that the cable will not hang down and rub on the dust shields (or catch in the mechanism while the dust shields are removed). A cable deflector attached to the escapement bracket prevents the velocity control cable from getting behind the carrier. As shown in figure 9-68, the cable is also clamped along the rear edge of the dust shields by a center cable clamp on the powerframe and a guide lug on the right-hand dust shield. The center cable clamp maintains the cable in its correct lateral position so that the carrier is free to travel the entire length of the carriage without being restricted by the cable.

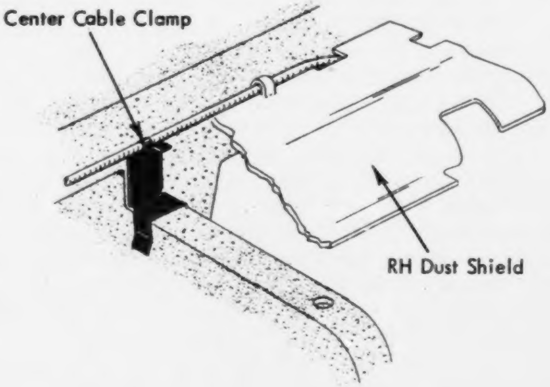


91.489
Figure 9-67. —Cable guide and cable deflector.

IMPRESSION CONTROL MECHANISM (STICK SHIFT).—The impression made by the typing element is determined by the velocity of the typing element upon impact with the paper. When theimpression control lever is pulled forward to a new position, the pin on the lower extension moves toward the rear in the forked slot of the follower, thereby increasing the amount of powered travel that the typing element receives. The forked slot in the follower is designed so that most of the change in powered travel is felt



91.488
Figure 9-66. — Print cam follower stop screw.



91.490
Figure 9-68. —Center cable clamp.

as a change in the rest position of the type head and not as a change in the amount of free flight (determined by the limit of powered travel). Throughout the entire range of the impression control lever, the free flight of the type head should change slightly (approximately .015). This is necessary in order to maintain the correct timing relation between type head detenting and type head printing as the velocity of the type head is increased or decreased by the impression control lever. In other words, by increasing or decreasing the amount of free flight to compensate for a change in type head velocity, the print time of the type head remains constant in the machine cycle regardless of the impact velocity of the typing element.

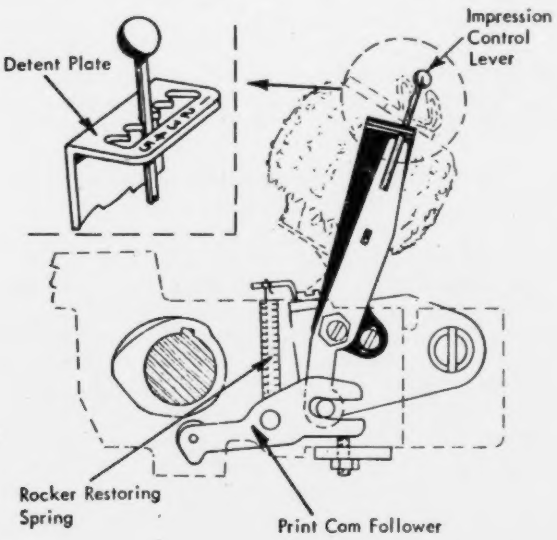
Note in figure 9-69 that the rocker is now spring-loaded back to rest by a large extension spring (rocker restoring spring). The dual velocity print cam eliminates ring and cylinder.

PRINT ESCAPEMENT

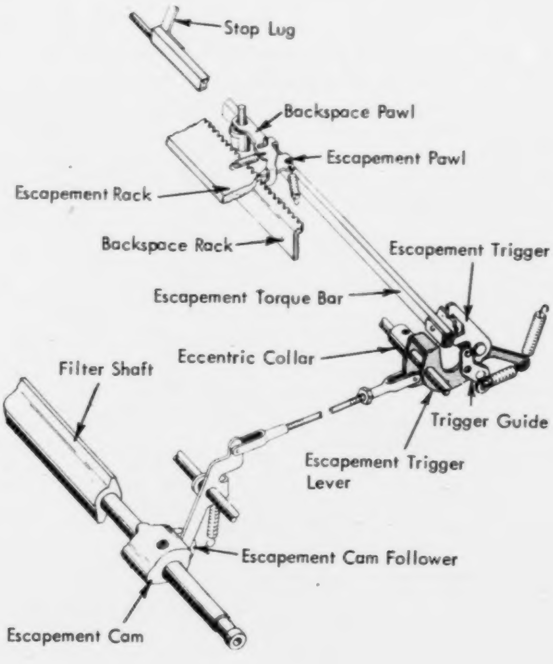
A print escapement only occurs when a character keylever is depressed. The escapement mechanism controls the movement of the carrier along the writing line. The print escapement mechanism consists of the escapement bracket assembly, escapement rack, escapement torque bar, escapement trigger lever assembly, and the escapement cam and follower.

ESCAPEMENT BRACKET ASSEMBLY.—Refer to the drawing in figure 9-70. The escapement bracket assembly is a plate attached to the rear of the carrier so that it moves with the carrier. The escapement rack is mounted solidly to the powerframe just behind the carrier and beneath the escapement bracket. A stud at the left rear corner of the escapement bracket mounts the escapement pawl to the bottom of the bracket so that it pivots front to rear. Having the escapement rack stationary and the escapement pawl movable is directly opposite to the arrangement on conventional typewriters. A small spring from the pawl to the bracket exerts a force to the right and forward on the escapement pawl.

Other components are present on the escapement bracket that are only indirectly related to the escapement mechanism. Pivoting on the same stud with the escapement pawl are the backspace pawl, the tab lever, and the tab lever


Impression Control Lever
Detent Plate
Rocker Restoring Spring
Print Cam Follower

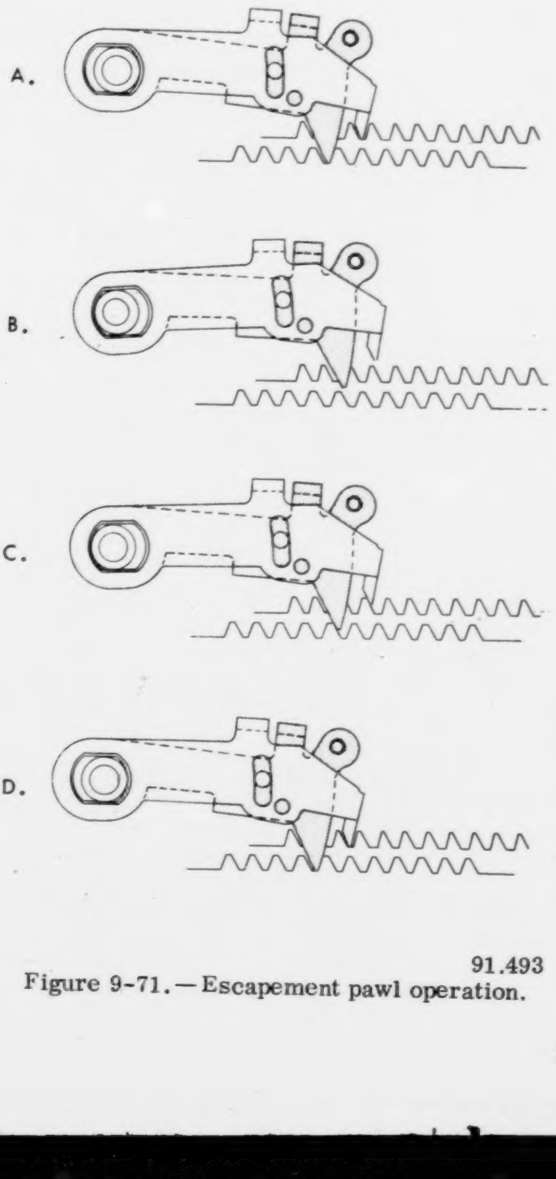
91.491
Figure 9-69.—Impression control mechanism.


Stop Lug
Backspace Pawl
Escapement Pawl
Escapement Rack
Backspace Rack
Escapement Trigger
Escapement Torque Bar
Eccentric Collar
Filter Shaft
Trigger Guide
Escapement Trigger Lever
Escapement Cam Follower
Escapement Cam

91.492
Figure 9-70.—Print escapement mechanism.

trigger. The tab lever latch mounts on the right side of the escapement bracket.

The escapement pawl contains an elongated hole at its mounting point that allows .022" lateral movement in the pawl. While the pawl is engaged in the rack, the force of the mainspring holds the carrier to the right so that the pivot stud rests against the end of the elongated hole, as illustrated in figure 9-71A. The escapement operates when the escapement pawl is forced to the rear out of engagement with the rack teeth as in figure 9-71B. Because it is relatively light in weight, the pawl is snapped to the right by the pawl spring as soon as the pawl clears the rack tooth. The escapement pawl is allowed to move back to the front into engagement with the next tooth, as in figure 9-71C. The carrier then moves to the right until it comes to rest against the escapement pawl as in figure 9-71D.



91.493
Figure 9-71.—Escapement pawl operation.

The amount the carrier is allowed to move is determined by the distance from one escapement rack tooth to the next. This is known as the pitch of the machine and is expressed in terms of teeth or spaces per inch. Two pitches are available on the Series 72. They are 10 and 12 pitch. The type style to be used is determined largely by the pitch of the machine, because the larger type styles require more space for each character. The pitch and type style together are determined by the operator's preference and by what the machine is to be used for.

The carrier and escapement pawl must be moved to the left for a backspace operation. Because the backspace pawl is mounted to the escapement bracket, movement of the backspace pawl to the left forces the carrier and escapement pawl to the left. The backspace pawl is just above the escapement pawl, but its tooth extends below the escapement pawl. It is held in mesh with the backspace rack by a small extension spring similar to that of the escapement pawl. The backspace rack is mounted to the rear of the powerframe by shouldered screws through elongated holes in the rack. This mounting arrangement allows lateral movement of the rack. Movement of the rack toward the left forces the backspace pawl to the left to cause a backspace operation. (The backspace operation is pointed out here because of its close association with the escapement mechanism. It is discussed more fully in the backspace section.)

Figure 9-71, A, illustrates a slight clearance between the working surfaces of the backspace pawl and a tooth on the backspace rack when the escapement pawl is holding the carrier. This clearance is necessary for proper operation of the backspace mechanism. The clearance insures that the backspace pawl will properly reenter the backspace rack at the completion of each backspace operation during the repeat operation. (This is when the escapement pawl is holding the carrier and the backspace rack is restoring back to its rest position.)

The backspace pawl is in mesh with its rack when in the rest position. This means that the backspace and escapement pawls must be removed from their racks for the carrier to move to the right during forward spacing. The backspace pawl requires .022" of elongated motion in its mounting hole so that it can operate in unison with the escapement pawl during an escapement operation. Without the elongated motion, the backspace pawl could restore back into the same rack tooth before the carrier began to move during an escapement operation. This could cause partial or half spacing, as the two pawls would alternate holding the carrier during an escapement operation. The backspace and escapement pawls are pinned together so that they always move together laterally but front to rear independently. The reason for this is covered in the backspace section.

TORQUE BAR.—Refer again to figure 9-70. The torque bar is a flat bar that pivots between the sides of the powerframe just to the rear of the backspace and escapement racks. Its purpose is to trip the backspace and escapement pawls out of their respective racks. The left end pivots in a hole in the powerframe casting. A small C-clip holds the right end in a large mounting plate on the powerframe. The rest position of the torque bar is controlled by an adjustable stop which mounts on the right-hand tab rack mounting plate and contacts a lug on the right-hand end of the torque bar.

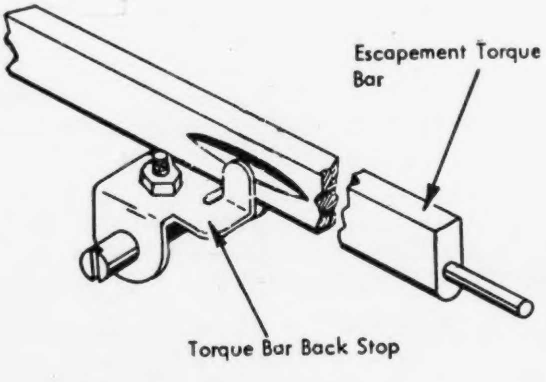
The pivot point of the torque bar is near the bottom of the bar. When the torque bar pivots, the top of the bar moves to the rear. The escapement pawl and backspace pawl each have a lug that extends down just behind the torque bar. As the top of the torque bar pivots to the rear, it forces the lugs of the pawls to the rear, causing the tips of the pawls to be tripped out of their racks. Rotation of the escapement torque bar is instantaneous and just sufficient to trip the pawls out of their racks. The torque bar is immediately rotated back to the rest position by an extension spring, located at the right end. This allows the pawis to reenter their racks to limit the carrier movement to one space.

Because of the force required to trip the pawls out of their racks, the torque bar tends to bow toward the front instead of pushing the pawls to the rear. The tendency increases as the carrier moves toward the middle of the torque bar. Bowing of the torque bar could keep the escapement from tripping. To overcome this, the pawl pivot stud has a large head that extends down in front of the torque bar to stop any bowing toward the front. The torque bar actually pries against the pawl stud to trip the pawls from the rank. The pawl stud that has an eccentric head so that the escapement trip in the center of the torque bar can be adjusted to be the same as at the ends.

On long carrier machines, additional support is given to the escapement torque bar, as shown in figure 9-72 to prevent it from bowing to the rear. A backstop mounted to a stud in the machine powerframe provides the necessary backing.

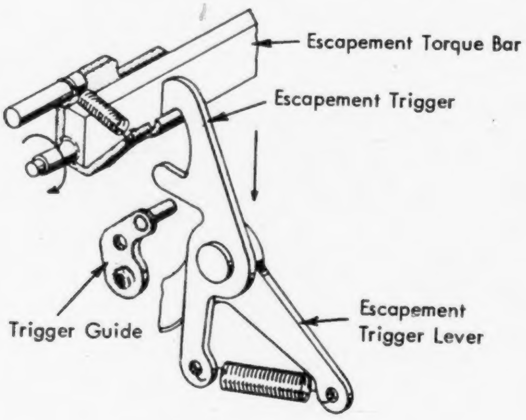
ESCAPEMENT TRIGGER.—The escapement trigger rotates the torque bar in order to start an escapement operation. The right end of the torque bar contains a lug that extends to the rear. The escapement trigger hooks over the lug and pulls downward to cause the torque bar to rotate. Consult figure 9-73 and you will see that the trigger pivots on the escapement trigger lever and is held forward over the torque bar lug by an extension spring between the bottom of the trigger and a rear extension of the trigger lever.

The trigger lever pivots on a shaft on the operational bracket mounted to the rear of the powerframe just below the right end of the torque bar. Downward movement of the trigger lever carries the trigger down to rotate the torque bar. The trigger lever is restored and held in the rest position by an extension spring from the rear of the lever up to a rear extension of the operational latch bracket. The trigger lever is cam operated; therefore, it can only restore as fast as the cam can rotate from the high point to the low point. The torque bar must be allowed to restore more quickly so that the escapement

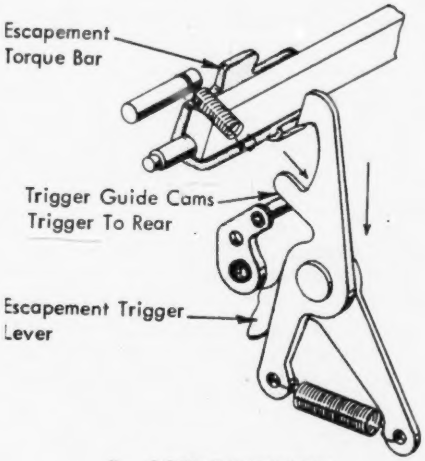


91.494

Figure 9-72.—Torque bar backspace.


Escapement Torque Bar
Escapement Trigger
Trigger Guide
Escapement Trigger Lever

A. REST POSITION


Escapement Torque Bar
Trigger Guide Cams Trigger To Rear
Escapement Trigger Lever

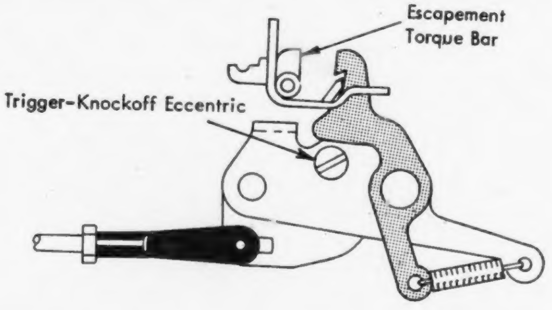
B. ACTIVE POSITION

91.495
Figure 9-73.—Escapement trigger operation (old style).

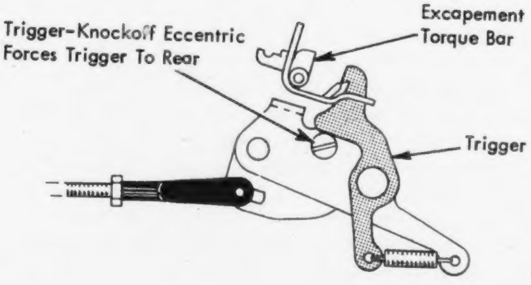
pawl can re-enter the correct rack tooth. Delaying the torque bar restoration can result in escapement skipping, especially on 12-pitch machines.

To insure that the torque bar can restore quickly enough, the trigger is disengaged from the torque bar lug just after the escapement trip occurs. The operational latch bracket is formed to the rear at the right side. Attached to the inside of this rearward portion is a small plate called the trigger guide, shown in figure 9-73A. The trigger guide has a stud extending to the left front of the escapement trigger. A beveled portion of the trigger contacts this stud as the trigger moves down, causing the trigger to be cammed to the rear off the lug on the torque bar, as shown in figure 9-73B. The torque bar can then restore without waiting for the restoration of the trigger lever. The new style escapement trigger operation is basically the same as the old style except that the trigger knockoff action comes from a screw with an eccentric head that mounts on and moves with the escapement trigger lever shown in figure 9-74.

ESCAPEMENT CAM.—Now, refer again to figure 9-70. Because an escapement operation is necessary each time a character prints, the power


Escapement Torque Bar
Trigger-Knockoff Eccentric

A. REST POSITION


Trigger-Knockoff Eccentric Forces Trigger To Rear
Excapement Torque Bar
Trigger

B. ACTIVE POSITION

91.496
Figure 9-74.—Escapement trigger operation (new style).

to trip the escapement is taken from a portion of the cycle mechanism. A small double-lobed cam, called the escapement cam, is attached to the right end of the filter shaft just inside the powerframe. Each time a cycle operation occurs, the filter shaft operates the cam 180°. The escapement cam follower pivots on a long pin located in a bracket just to the rear of the filter shaft. A roller at the bottom of the follower is moved to the rear by a lobe of the cam each time a cycle operation occurs. This causes the link at the top of the cam follower to pull forward on the bottom of the escapement trigger lever. The link is connected to the trigger lever below its pivot point; therefore, a forward pull causes the trigger to move down at the rear and operate the torque bar.

Because the carrier is relatively light and moves quickly, the escapement trip must not occur before the character prints. If it did, the carrier might move before the character print or might move while the character is printing. This would result in an uneven left margin or poor horizontal alignment and possible smearing of the character, depending upon the timing of the trip. To eliminate this possibility, the escapement cam is timed so that the escapement trip occurs just after the type head leaves the platen to restore to rest. On the Model 721 only, a small eccentric collar on the pivot pin prevents the pin from bowing forward due to the pull of the escapement trip link. The collar braces the pivot pin by resting against the bracket in which the pivot pin is mounted. Without the collar, some the trip link motion would be lost in the flexing of the pivot pin. Escapement failure would result if not enough trip link travel remained to remove the pawls from the rack.

MAINSPRING

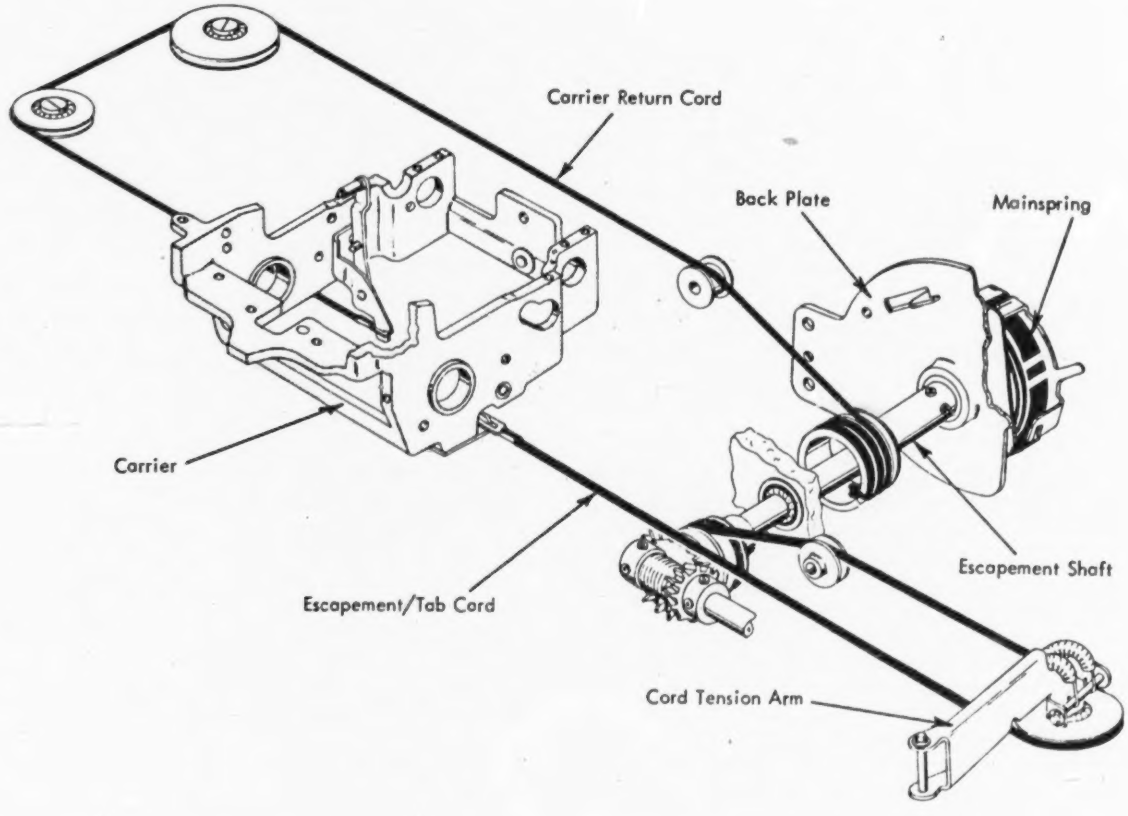
Anytime the escapement and backspace pawls are removed from their racks, the carrier is pulled toward the right. The mainspring supplies the tension for all movement of the carrier toward the right. It is located at the right rear corner of the machine. Notched lugs of the mainspring cage fit into slots in the backplate shown in figure 9-75. The cage is turned counterclockwise (as seen from the rear) so that it locks into position.

To change the tension of the mainspring, you turn the entire mainspring cage to a new location. When working with the mainspring, be extremely careful to keep it under control.

The center of the backplate contains a ball bearing assembly that supports the rear end of the escapement shaft. The shaft extends to the rear into the mainspring, where a hub is set screwed to the shaft. The inner end of the mainspring is rolled so that it fits into a groove in the hub and supplies rotary force to the hub and escapement shaft. The escapement shaft extends forward through another ball bearing assembly in the powerframe and has a drum attached at the forward end. This is called the cord drum gear and is spirally grooved to accept the escapement/tab cord. The grooves prevent the cord from piling up on the drum, insuring uniform tension and minimum wear. The escapement/tab cord is a small, round, nylon-covered linen cord. The drum end of the cord is knotted and fits into a slot at the rear of the drum. The cord makes several turns around the drum and rides up over a guide roller before passing through the right side of the machine. Just outside the machine the cord passes around a pulley and extends back to the left where it is attached to a hook on the carrier assembly. As the mainspring turns the escapement shaft, the drum winds up the cord to move the carrier to the right.

More than one operation is performed by the escapement shaft. The rear teeth at the front of the cord drum are involved in both the carrier return and tabulator operation. Between the powerframe and the backplate is another cord drum with a cord attached to it similar to the escapement/tab cord. This cord is attached to the left side of the carrier and exerts a pull to the left during carrier return. These operations are fully covered in their particular sections. However, the carrier return cord drum is significant in the escapement mechanism, because it must pay out cord in order for the carrier to move to the right. Likewise, the escapement/tab cord must be payed out from its drum in order for the carrier to return to the left. The constant jerk and pull to which the cords are subjected may tend to stretch them slightly. This could cause the cords to become slack, causing erratic movement to the carrier. A method has been provided whereby the slack is automatically removed from both cords.

Outside the powerframe, the pulley that guides the escapement cord is mounted to the cord tension arm pivoted at the front. A pair of spiral springs arched between the arm and a pin on the powerframe apply a constant pressure toward the right. The pressure is sufficient to keep the slack out of the escapement cord. This,



91.497

Figure 9-75.—Mainspring and cord system.

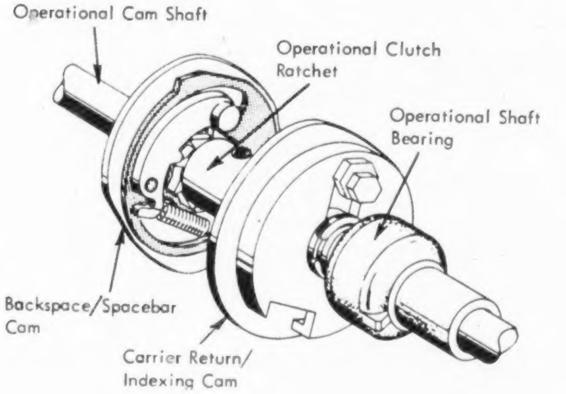
in turn, rotates the escapement shaft enough to keep the carrier return cord tight.

OPERATIONAL CAMS AND CONTROL MECHANISM

All powered functional operations are driven by the operational camshaft, located on the right side midway back in the machine. The powered operations are the spacebar, backspace, carrier return, indexing, and shift. The tabulator is manually operated and is the only nonpowered functional operation. The spacebar, backspace, carrier return, and indexing mechanisms are operated by two cam assemblies, mounted on the operational camshaft. The shift is driven by a spring clutch at the right end of the shaft outside the powerframe.

OPERATIONAL CAMS.—The two operational cams are located on the right side of the operational shaft just inside the powerframe. Look at figure 9-76. The left-hand cam is a double-lobed cam that requires only 180° of rotation to complete one operation. Its purpose is to power the spacebar and backspace mechanisms. The righthand cam is a single-lobed cam requiring 360° of rotation to complete one operation. It powers the engaging of the carrier return mechanism and operates the indexing mechanism. Each operational cam must power two functions. The mechanism to be operated is selected by depressing the desired keylever. The selection operation is discussed later in this section.

Both the single-and double-lobed cams have the same rise from the low point to the high


Operational Cam Shaft
Operational Clutch Ratchet
Operational Shaft Bearing
Backspace/Spacebar Cam
Carrier Return/ Indexing Cam

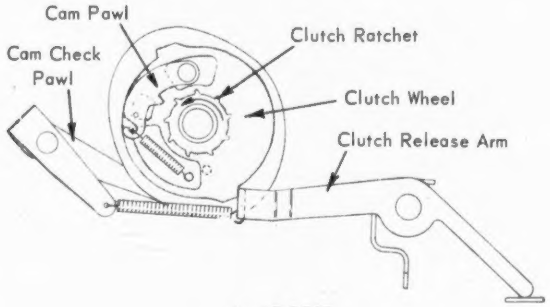
91.498

Figure 9-76.—Operational cams.

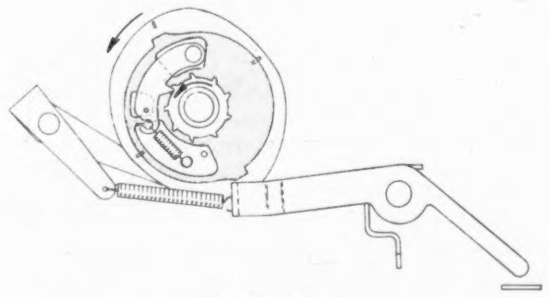
point. The double-lobed cam completes any operation sooner than the single-lobed cam, because it requires only 180° rotation compared to 360° for the single-lobed cam. The faster double-lobed cam is used in the spacebar mechanism, because the spacebar action must be as fast as the print action in order to maintain typing rhythm. The backspace operation must operate quickly in order to provide rapid positioning of the carrier; therefore, it also uses the double-lobed cam. Both the carrier return and indexing keylevers have a repeat/nonrepeat feature. When operated in the repeat position, they cause rapid indexing of the platen. Operating too rapidly could create inaccurate indexing due to platen overthrow and failure of the index pawl to restore quickly enough; therefore, the slower single-lobed cam is used to operate the carrier return and indexing mechanisms.

A ratchet, called the operational clutch ratchet, is setscrewed to the operational camshaft. Take a look at the drawing in figure 9-76 and you can see that the cam assemblies are C-clipped into position on the shoulders of the ratchet, one on each end. The operational camshaft and clutch ratchet are allowed to turn while the cam assemblies remain stationary. Steel sleeves fitted into the cam bodies act as bearings for the cams.

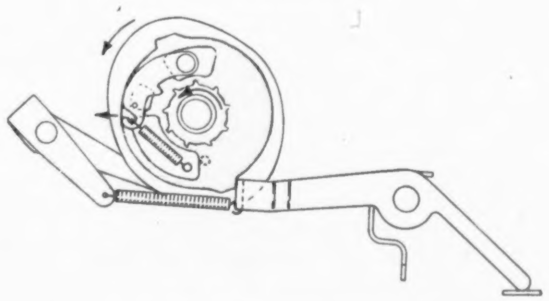
A cam rotates only when a particular operation is desired. In order for the cam to rotate it must be "locked" to the operational clutch ratchet. Now turn to figure 9-77A. As in the drawing, each cam has a pawl mounted to it in such a manner that the pawl can be pivoted into engagement with the rotating operational clutch ratchet. Whenever the pawl is permitted to engage in the clutch ratchet, the cam rotates with the ratchet in the manner indicated in figure 9-77B. The operational cam pawl is prevented from engaging the clutch ratchet by a disc called the clutch wheel, shown in figure 9-77A. The clutch wheel is attached to and forms a part of the cam assembly. The disc is mounted to the



A. AT REST.



B. CAM ACTIVE.



C. CLUTCH PAWL BEING DISENGAGED.

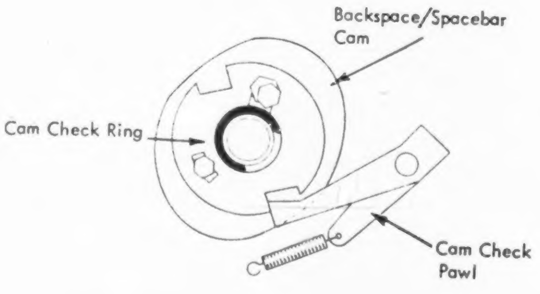
91.499

Figure 9-77.—Operational cam.

cam assembly so that the cam pawl operates through an oversized hole in the disc. The clutch wheel is free to rotate on the cam assembly, but its movement is restricted by contact with the cam pawl. A pin at the tip of the pawl fits into another hole in the clutch wheel that has one side beveled, as shown in figure 9-77B. Movement of the cam while the clutch wheel is held stationary causes the pin on the pawl to slide up the beveled side of the hole and disengage the pawl from the ratchet. A drawing of this is in figure 9-77C.

Movement of the clutch wheel is controlled by the clutch release arm pivoted on a shaft below and to the rear of the cam assembly shown in figure 9-77A. The clutch wheel has a tooth that contacts the end of the clutch release arm as the cam assembly rotates. The clutch release arm stops the movement of the wheel. Further rotation of the cam causes the pawl to be disengaged from the ratchet as described. When the clutch release arm is moved down, the clutch wheel is released as shown in figure 9-77B. The cam pawl spring is then allowed to pull the pawl into engagement with a tooth of the clutch ratchet by merely rotating the clutch wheel out of the way. As soon as the clutch release arm is allowed to restore, it is pulled by its spring back up into position to contact a tooth of the clutch wheel. There are only two such teeth for the double-lobed cam and only one for the single-lobed cam. The cam assembly is driven 180° for the double-lobed cam and 360° for the single-lobed cam before the clutch release arm contacts and stops a tooth of the clutch wheel.

Rotation of the double-lobed cam through 360° allows the high point of the cam to operate the particular function involved. The cam pawl spring tries to pull the pawl into engagement with the clutch ratchet. Unless the cam is held in position after the pawl is disengaged from the ratchet, the spring will cause the cam to creep backward, allowing the pawl to partially engage the ratchet and create a loud buzzing sound. It cannot fully engage the ratchet, because it would be disengaged immediately as previously described. To prevent backward creep of the operational cams and the resulting noise, there is a cam check pawl for each cam. The check pawl engages a notch in the cam assembly (as shown in fig. 9-78) as soon as it has rotated far enough for the cam pawl to be disengaged from the ratchet. The check pawls extend to the rear from a pivot pin located just in front of the cams. An extension spring from each check pawl to the clutch release arm maintains the two parts in the rest position. The notch engaged by the cam check pawl is in a disc-shaped part called the cam check ring. The ring is attached to the cam by two screws. An eccentric collar on one of the screws permits adjustment of the cam check ring.



91.500
Figure 9-78.—Operational cam check pawl.

OPERATIONAL CONTROL MECHANISM.—The operational control mechanism is a compact unit contained in a bracket located under the operational cams. The purpose of the mechanism is to select the function to be operated, control the movement of the cam, and transfer the cam motion to the selected operation. To fulfill these three purposes, each cam requires four basic parts in its control mechanism. They are: an interposer to select the operation and to help with the cam control, a clutch release arm to control the cam, a restoring device for the interposer, and a cam follower to transfer the cam motion to the operations. The principle of operation for both cam control mechanisms is the same; however, the parts design differs slightly.

Interposers.—Each mechanism operated by the cams requires an interposer to select the mechanism to be operated and to cause the cam to be engaged. Refer to figures 9-79 and 9-80. These four interposers operate front to rear through slots in the operational control bracket and are latched forward on an adjustable guide attached to the front of the bracket. A position for a fifth interposer is present in the operational control bracket. The fifth interposer is used in special applications of the machine and is not normally included in the mechanism. Each interposer is spring-loaded to the rear by an extension spring between the interposer and the rear of the

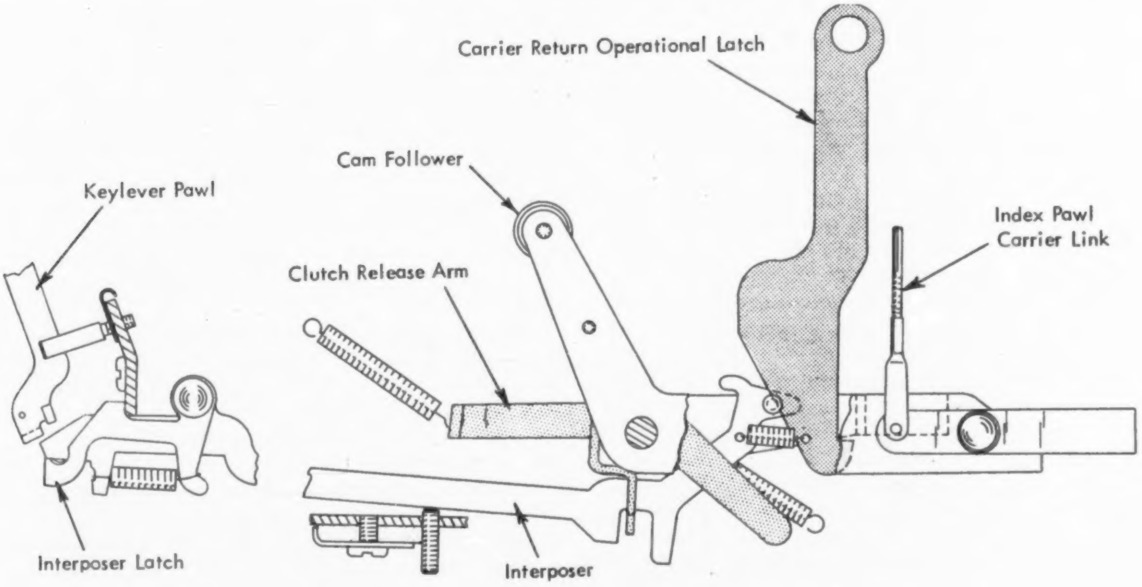

Carrier Return Operational Latch
Cam Follower
Keylever Pawl
Index Pawl Carrier Link
Clutch Release Arm
Interposer Latch
Interposer

Figure 9-79.—Carrier return/indexing operational control mechanism. 91.501

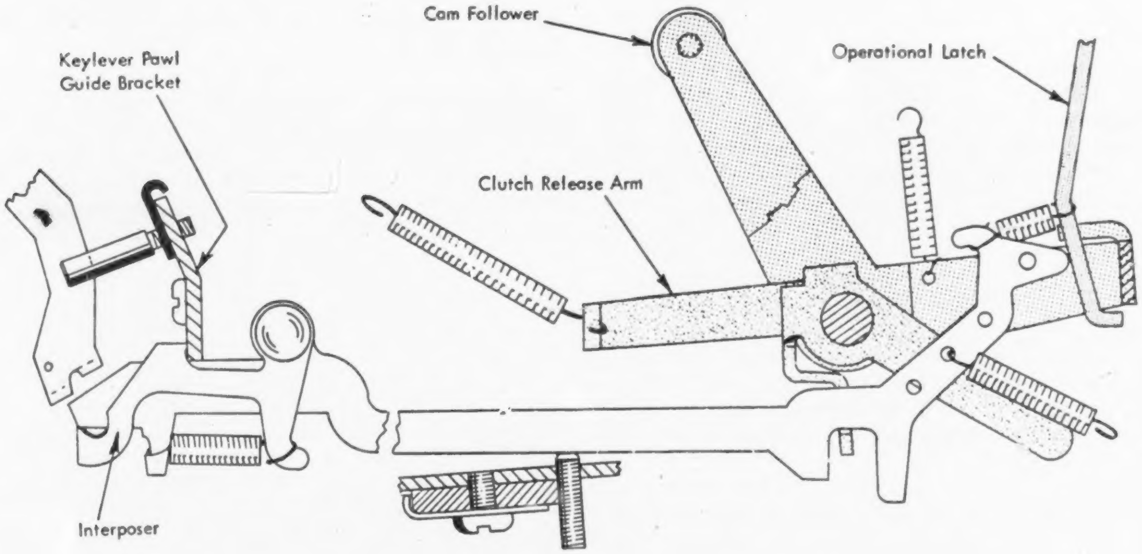

Cam Follower
Keylever Pawl Guide Bracket
Operational Latch
Clutch Release Arm
Interposer

Figure 9-80.—Back/spacebar operational control mechanism. 91.502

operational control bracket. Attached to the front of each interposer is a small pivoting latch. The latch is spring-loaded upward against the interposer. The top portion of the latch forms a hook for the interposer and hooks under the keylever pawl guide bracket (as in fig. 9-79) to hold the interposer forward.

When the interposer is pushed down the latch clears the bracket, allowing the interposer to be pulled to the rear to perform its function. The latch pivots on the interposer so that the entire interposer does not have to move down to allow the latch to relatch on the guide bracket as the interposer restores to the front. This insures positive relatching, because the latch can very quickly snap back up into the latched position after it has been cammed down by the guide bracket. The carrier return, indexing, backspace, and spacebar keylevers each have a pawl attached at the rear that extends down through a slotted guide stud to a position just above its own particular interposer. Depression of one of the keylevers causes a lug at the bottom of the keylever pawl to depress the interposer and release it to the rear.

Clutch Release Arm.—Two clutch release arms are present, one for each cam. The arms are identical in operation but slightly different in design to conform to their position in the machine. The release arms pivot on a shaft at the rear of the cams. Each clutch release arm has three extensions from the pivot. The forward extension blocks the clutch wheel to disengage the cam pawl from the ratchet. The lower extension is contacted by an interposer. The interposer pivots the forward extension down out of the path of the clutch wheel to allow the cam to be driven. In the rest position, the rear extension of the clutch release arm contacts the bottom of the operational control bracket. This controls the "bite" between the release arm and the clutch wheel to insure positive release action. The clutch release arm is restored and held at rest by an extension spring between the forward extension and the cam check pawl.

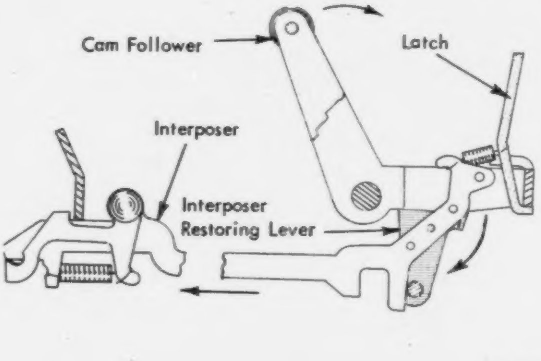
Cam Follower.—Again, look at figures 9-79 and 9-80. Each cam has a cam follower designed to convert the rotary motion of the cam into vertical linear motion at the rear. The cam followers are bellcrank devices mounted just to the rear of the cams. The cam followers pivot around the same pivot shaft that supports the clutch release arms. A roller at the top of each cam follower is in continuous contact with its particular cam.

The carrier return/indexing cam follower (fig. 9-79) extends to the rear where it is designed in the form of a bail. When the cam operates, the rear of the follower moves down as the cam forces the roller to the rear. A link attached near the rear of the cam follower operates the indexing mechanism. Each time the cam operates, an indexing mechanism restores the cam follower and holds the roller against the cam.

The backspace/spacebar cam follower, shown in figure 9-80, is designed to operate three mechanisms. In normal applications of the machine, only the backspace and spacebar are present. In input/output typewriters the tabulator is also powered by the cam. Because it has three positions to operate, the cam follower must be wider than that of the carrier return.

An extension spring from the cam follower to the operational latch bracket restores the cam follower and holds the roller against the cam. Pressure of the cam follower roller against the cam is essential for proper operation of each cam. The spring tension forces the cam follower from the high point to the low point of the cam. This accelerates the cam enough to give the overthrow required to disengage the cam pawl from the ratchet and to allow the check pawl to engage the check ring.

Interposer Restoring Lever.—Look at figure 9-81. After an interposer has been released to the rear to begin an operation, it must be restored forward so that the clutch release arm may pivot back to its rest position to stop the



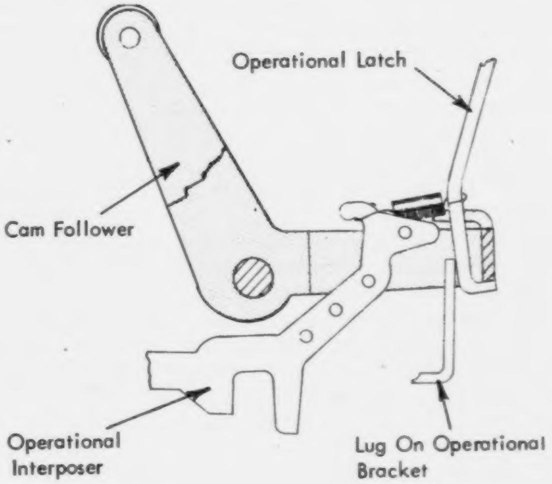
91.503
Figure 9-81.—Interposer restoring operation.

action of the cam. The interposers are restored by a bail-shaped part that pivots between the sides of the operational control bracket and is located just to the rear of the interposers. A lug at cam side of the interposer restoring lever is in contact with the cam followers. Operation of either cam follower pivots the bottom of the restoring lever forward. The restoring lever, in turn, forces the interposer forward where it can latch in the rest position.

OPERATIONAL SELECTION.—Refer to figure 9-79. In addition to causing cam release, the interposer must set up the mechanism to be operated. This is true of all except the indexing interposer. Because the indexing mechanism is directly connected to the cam follower, merely releasing the cam results in an indexing operation.

Look at figures 9-79 and 9-80 again. The backspace, spacebar, and carrier return interposers each have a small, hooklike operational latch resting against the rear of the interposer. A small extension spring maintains the latch against the interposer. Each latch is suspended from its own particular mechanism located above the rear of the interposer. Pulling any one of the latches down causes it to operate the mechanism involved. The hook portion of the operational latch rests just in front of the cam follower. When one of the interposers is snapped to the rear, the latch for that interposer is pushed to the rear, where it hooks under the cam follower. The cam follower is then operated to pull down on the latch and actuate the selected mechanism.

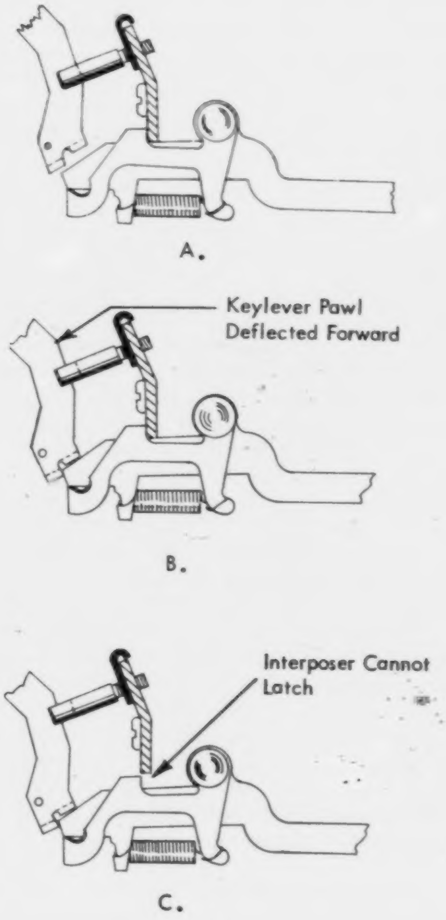
Look at figure 9-81. As the cam follower is operated, the interposer is restored to the front by the restoring lever. This causes the spring between the interposer and the operational latch to extend. Extending the spring tends to pull the latch out from under the cam follower before the operation is completed. To insure a complete operation, the latch is locked to the rear as soon as the operation begins. As the latch is pulled down by the cam follower, it moves down behind a lug of the operational control bracket, as shown in figure 9-82. The lug prevents any forward movement of the latch until the operation is completed and the cam follower restores. The latch is then pulled forward into its rest position against the interposer. The carrier return latch is not locked to the rear, because its beveled forward edge permits it to remain in contact with the interposer throughout the operation.



91.504
Figure 9-82.—Operational latch locked to the rear.

OPERATING SEQUENCE.—As the desired keylever is depressed, a lug of the keylever pawl contacts an interposer, forcing it down to release it from the guide bracket. The interposer is pulled to the rear by its spring. A lug on the interposer contacts the clutch release arm, rotating it down at the front to allow the cam clutch to be engaged. At the same time, the interposer forces its selective latch to the rear, pushing it under the cam follower. The cam is driven by the clutch ratchet, causing the cam follower to move from the low point to the high point of the cam. Movement of the cam follower pulls down on the operational latch to power the mechanism and, at the same time, actuate the interposer restoring lever to restore the interposer forward. The clutch release arm restores into the path of the clutch wheel ready to disengage the cam clutch. The cam follower passes the high point of the cam and restores to the rest position as it reaches the low point. The operational latch is snapped forward against its interposer into the rest position, and the operation is completed.

REPEAT/NONREPEAT.—Each of the four mechanisms operated by the operational cams is equipped with a repeat/nonrepeat feature. When the keylever is depressed to its first limit, only a single operation occurs. Further depression of the keylever causes the first limit to yield and allow a repeating action. Look at figure 9-83A. In order to obtain either a single or a repeating operation, two lugs are needed on each keylever pawl. The front lug is just above the tip of the interposer when both lugs are at rest as in figure 9-83A. When the keylever is depressed, the front lug causes the interposer to be released. As the interposer snaps to the rear, it moves out from under the lugs of the keylever, which is held depressed to its first limit, and the end of the interposer contacts the rear lug of the keylever pawl as it restores to the front. The interposer forces the pawl forward and relatches on the keylever pawl guide bracket as in figure 9-83B. When the keylever is released, the keylever pawl then resets to the rear above the interposer. When the keylever is not released, the rear lug on the keylever pawl remains in position to release the interposer.

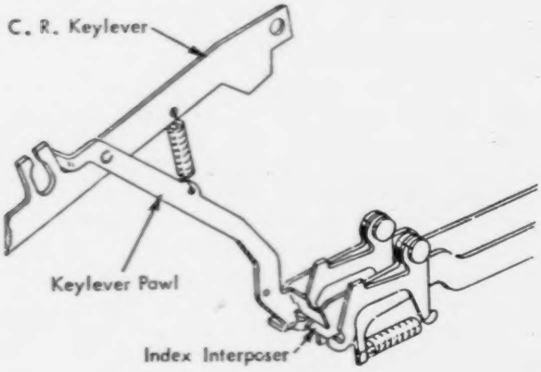


91.505
Figure 9-83.—Keylever pawl operation.

Depression of the keylever past its first limit causes the rear lug to trip the interposer from the latch bracket as in figure 9-83C. The interposer moves to the rear as before, but it cannot move far enough to get out from under the rear lug of the keylever pawl. Each time the interposer is restored to the front, it is prevented from latching as in figure 9-83C, because the rear lug of the keylever pawl continues to hold it down. Because the interposer cannot latch, it is snapped back to the rear by its spring to operate the clutch release arm and to push the operational latch under the bail of the cam follower. Each time the cam operates, this action of the interposer is repeated, causing a continuous operation.

There is no operational latch for the indexing mechanism; therefore, the index interposer alone operates the clutch release arm to cause a continous cam operation. When the carrier return keylever is operated in the repeat position, it is always for the purpose of creating a repeat indexing operation with the carrier at the left margin. This is more convenient for the operator than using the index keylever, which was designed primarily for indexing with the carrier away from the left margin. One operation of the carrier return interposer causes an index operation plus a carrier return operation. Only an indexing operation is desired thereafter. Each time the carrier return interposer moves to the rear, however, the operational latch is moved under the cam follower to cause a carrier return operation.

It is undesirable and unnecessary to have a repeating carrier return action at the left margin because of the shock of the carrier repeatedly striking the left margin. Therefore, the carrier return interposer is not used for a repeating operation. When the carrier return keylever is depressed and held down for a single operation, the interposer operates to the rear and is restored as on the other mechanisms. The interposer forces the keylever pawl forward slightly in order to latch. The rear of the keylever pawl, instead of being above the carrier return interposer, is formed to the right above the index interposer. In figure 9-84, you can see that depressing the carrier return keylever past its



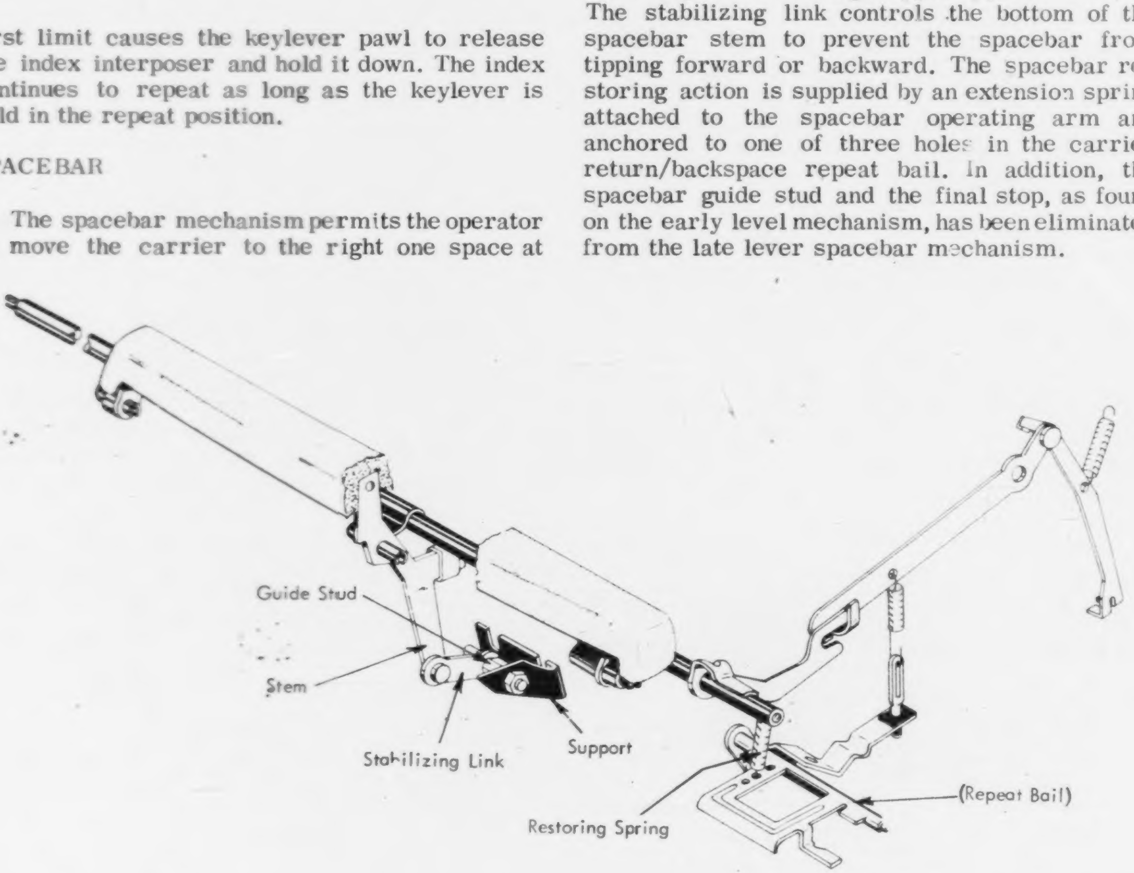
91.506
Figure 9-84.—Repeat carrier return operation.

first limit causes the keylever pawl to release the index interposer and hold it down. The index continues to repeat as long as the keylever is held in the repeat position.

SPACEBAR

The spacebar mechanism permits the operator to move the carrier to the right one space at a time without typing a character on the paper. It is used mainly for spacing between words, but it may also be used to space the carrier quickly to any point toward the right on the writing line. The space bar operates by tipping the escapement pawl and backspace pawl out of their racks as on a print escapement operation. The two escapement operations are identical except for the method of actuating the escapement trigger lever.

SPACEBAR LEVER MECHANISM (LATE LEVEL).—In the late lever spacebar stem, a stabilizing link has been attached to the bottom of the stem by a shouldered rivet. Turn to figure 9-85. The rear portion of the stabilizing link mounts on and pivots around an adjustable guide stud. This stud is fastened to a support on the front keylever bearing support by two screws. The stabilizing link controls the bottom of the spacebar stem to prevent the spacebar from tipping forward or backward. The spacebar restoring action is supplied by an extension spring attached to the spacebar operating arm and anchored to one of three holes in the carrier return/backspace repeat bail. In addition, the spacebar guide stud and the final stop, as found on the early level mechanism, has been eliminated from the late lever spacebar mechanism.



91.507
Figure 9-85.—Spacebar lever mechanism.

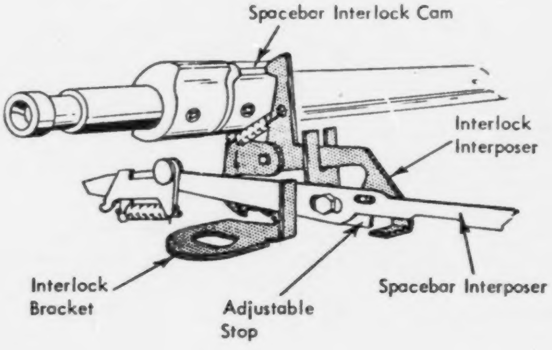
SPACEBAR LOCKOUT (NEW STYLE).— Look at figure 9-86. The spacebar interlock mechanism is mounted within the operational control bracket just below the filter shaft. It consists of a bracket an interlock interposer (which acts as a cam follower), and an interlock cam mounted on the filter shaft. When the filter shaft is in its rest position, the upper extension of the interlock interposer rests on the high point of one of the lobes on the interlock cam. This allows the horizontal lug on the lower extension of the interlock interposer to just clear the adjustable stop on the spacebar interposer as it operates to the rear during a spacebar operation.

Whenever a print operation occurs, the filter shaft and interlock cam begin to turn, causing the rear portion of the interlock interposer to rise into the operating path of the spacebar interposer. If the spacebar interposer is then released, the interlock interposer interrupts and stores the rearward travel of the spacebar interposer until the filter shaft completes its cycle. At this time, the spacebar interposer is released to finish its rearward travel, and the spacebar operation continues. Note that the interlock interposer is springloaded into its active position and powered to its rest position. This is to prevent breakage should both the spacebar and print operation be operated simultaneously.

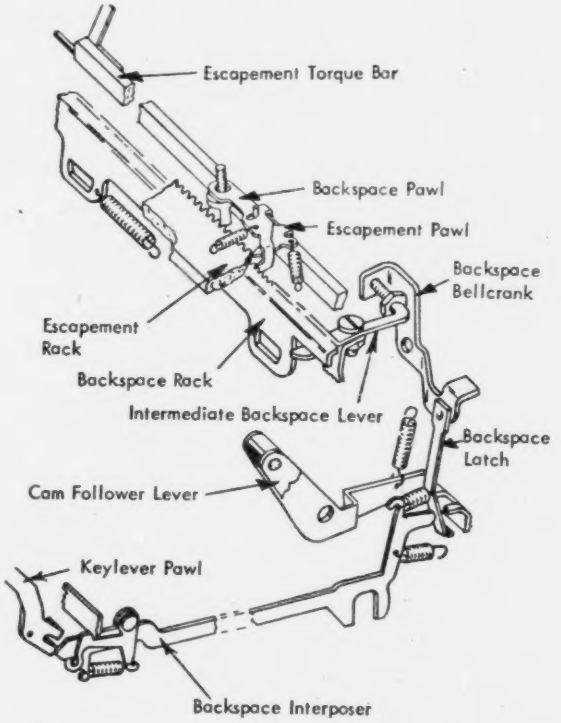
BACKSPACE

The backspace mechanism provides the operator with a method of positioning the carrier to the left, one space at a time. It is used primarily in error correction and in centering headings, but it may also be used to position the carrier quickly to any point toward the left on the writing line.

Look at the drawing of the backspace mechanism in figure 9-87. The backspace operates by forcing the carrier to the left until the escapement pawl clicks from one tooth of the escapement rack to the next. The backspace pawl is mounted on the escapement bracket with the escapement pawl so that movement of the backspace pawl to the left also moves the carrier and escapement pawl to the left. The tip of the backspace pawl engages the teeth of a sliding backspace rack located on the back of the powerframe just below the escapement rack. Movement of the backspace rack to the left forces the backspace pawl to the left to cause the backspace operation. The backspace rack is spring-loaded toward the right by an extension spring between the rack and the operational latch bracket. Upon completion of the operation, the backspace rack restores to the right, causing


Spacebar Interlock Cam
Interlock Interposer
Interlock Bracket
Adjustable Stop
Spacebar Interposer

91.508
Figure 9-86. — Spacebar lockout — new style.


Escapement Torque Bar
Backspace Pawl
Escapement Pawl
Backspace Bellcrank
Escapement Rack
Backspace Rack
Intermediate Backspace Lever
Backspace Latch
Cam Follower Lever
Keylever Pawl
Backspace Interposer

91.509
Figure 9-87. — Backspace mechanism.

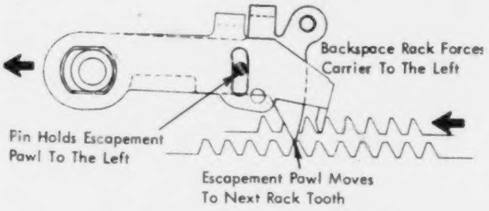
the backspace pawl to click from one tooth to the next in preparation for the next operation.

Refer now to figure 9-88. The escapement pawl has a small stud on its upper surface that fits into a slot in the backspace pawl. The slot is elongated front to rear to allow the escapement pawl to click from one escapement rack tooth to the next as the backspace rack forces the carrier to the left as in figure 9-88A. The slot also permits the backspace pawl to click into the next tooth as the backspace rack restores, as in figure 9-88B. Because of elongated pivot holes in the two pawls, the stud connection is necessary to insure that the pawls move together during a backspace operation and to prevent the backspace pawl from moving to the right as the backspace rack restores. Without the stud connection, the backspace rack would require .044" additional travel to compensate for the .022" elongation in each pawl.

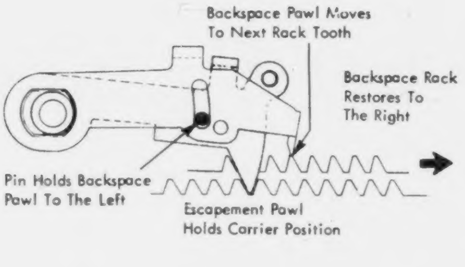
Refer again to figure 9-87. The backspace rack is actuated by a bellcrank pivoted on the front of the back plate. The bellcrank operates the rack through an adjustable intermediate lever pivoted at the top of the operational latch bracket. The backspace operational latch is mounted to the horizontal arm of the backspace bellcrank by a ball-shouldered rivet to permit free rotation of the latch. The latch extends down into position to hook under the bail of the operational cam follower. When the backspace interposer is released, the latch is pushed to the rear under the cam follower. Operation of the cam causes the cam follower to pull the latch down, rotating the backspace bellcrank. A large-headed adjusting screw on the vertical arm of the bellcrank operates the intermediate backspace lever to force the backspace rack to the left.

The intermediate backspace lever is adjustable forward or backward to obtain the proper throw of the backspace rack. The intermediate lever is adjusted farther forward on the 12-pitch machines than on the 10-pitch. The 12-pitch intermediate lever is shorter than the 10 pitch to prevent interference with the powerframe. It is too short to be used on 10-pitch machines. The 12-pitch intermediate lever is identified by a notch in the right side. The 10-pitch lever is unmarked.

Refer to the drawing in figure 9-89 and we see that the backspace interposer is released by depression of the backspace keybutton, located at the upper right-hand corner of the keyboard. The backspace keylever is mounted in the keyboard assembly in the same manner as the letter keylevers. An extension spring between the keylever and the keylever guard restores the keylever to the rest position. A keylever pawl attached to the rear of the keylever extends down through a slotted guide stud in position just above the backspace interposer. Depression of the keylever causes the interposer to be released to the


Backspace Rack Forces Carrier To The Left
Pin Holds Escapement Pawl To The Left
Escapement Pawl Moves To Next Rack Tooth

A. BACKSPACE ACTUATING STROKE


Backspace Pawl Moves To Next Rack Tooth
Backspace Rack Restores To The Right
Pin Holds Backspace Pawl To The Left
Escapement Pawl Holds Carrier Position

B. BACKSPACE RESTORING STROKE

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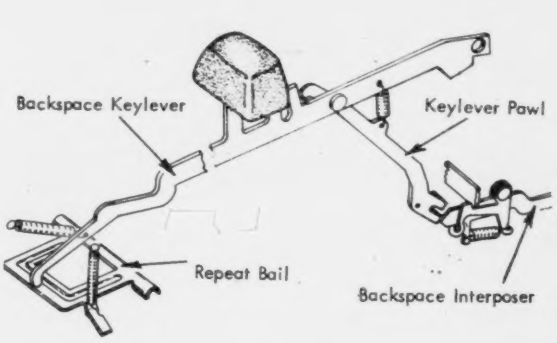
Figure 9-88.—Backspace strokes.


Backspace Keylever
Keylever Pawl
Repeat Bail
Backspace Interposer

91.511

Figure 9-89.—Backspace keylever mechanism.

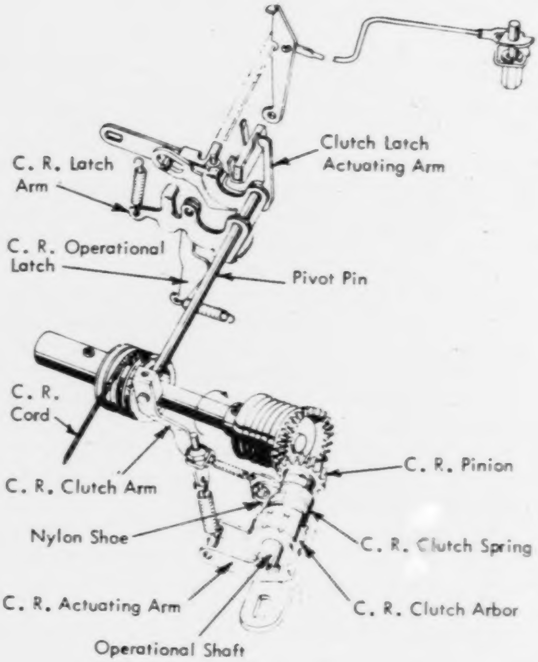
rear to begin the backspace operation. The upward travel of the keylever is limited by a fulcrum rod located at the top of the guide comb. A bail, located under the right front corner of the keyboard, determines the first limit for the keylever depression. The left end of the bail pivots in a small bracket attached to the bottom of the guide comb support. The right end pivots in a hole in the keyboard sideframe.

A lug on the right side of the repeat bail limits against the keyboard sideframe to determine the rest position of the repeat bail. An extension spring inside the sideframe holds the repeat bail in the rest position and offers a resistance to further depression of the keylever. When the keylever is depressed, the front of the keylever is forced down against the repeat bail. This stops the travel of the keylever and allows a single operation of the mechanism. Additional pressure on the keylever causes the repeat bail to yield allowing the keylever to move into the repeat position. Holding the keylever in the fully depressed position causes the keylever pawl to hold the interposer down, allowing a continous operation of the mechanism. The final travel of the keylever is reached when the keylever bottoms in the guide comb.

CARRIER RETURN

CARRIER RETURN. — The carrier return mechanism returns the carrier to the left margin and automatically line spaces the paper. Depressing the carrier return keylever into the repeat position causes additional line space operations. This can be done while the carrier is being returned, making it unnecessary for the operator to wait until the carrier reaches the left margin. Let's look at figure 9-90 to get a picture of this mechanism.

The carrier return operates by winding the carrier return cord onto a drum at the rear of the machine. The carrier return cord hooks to the bottom of the carrier, passes around two pulleys at the left, extends back to the right over a guide roller, and attaches to the carrier return cord drum. The drum has spiral grooves for winding up the cord as on the escape cord drum. The carrier return cord drum is attached by setscrews to the escapement shaft just in front of the mainspring. Rotation of the escapement shaft causes the drum to wind up the cord and move the carrier to the left. Movement to the left opposes the mainspring tension, causing the mainspring to tighten.



91.512
Figure 9-90. — Carrier return mechanism.

The power to rotate the escapement shaft in opposition to the mainspring is taken directly from the operational cam shaft. The escapement cord drum (at the front of the escapement shaft) has a beveled gear molded on its front. This beveled gear meshes with a small pinion gear on the operational shaft. The pinion gear pivots freely on the shaft between two C-clips.

A spring clutch rotates the pinion with the operational shaft. The pinion gear drives the escapement cord drum in a clockwise direction, causing the carrier return cord to wind onto its drum. The carrier return pinion has a hub that forms a part of the spring clutch. A second hub just to the left of the pinion is in continous rotation with the operational shaft. A clutch spring fits around the two hubs to complete the spring clutch. A steel band clamps the left end of the spring around its hub so that no slippage can occur at that point. The clamp causes the spring to rotate with the operational shaft. The shaft turns in the tightening direction of the spring, but no tightening occurs because the pinion hub is smaller than the inside diameter of the clutch spring. If the clutch spring is to tighten friction must exist between the spring and the hub it is to drive. Pressing the loose end of the carrier return clutch spring against the pinion hub causes the necessary friction, and the spring tightens around the hub and drives the pinion.

The spring is pressed against the pinion hub by a nylon shoe just to the rear of the carrier return pinion. The clutch spring decreases in diameter as it tightens around the pinion hub. The tension of the spring resists any change in size; therefore, when the pressure from the shoe is relaxed, the spring snaps back to normal size and ceases to drive the pinion. In order to obtain a full carrier return, the carrier return shoe must press the spring against the pinion hub and hold it there until the carrier has reached the left margin. It must then release the clutch spring to end the carrier return operation. The power to operate the shoe against the clutch spring is taken from the single-lobed operation cam. Depression of the carrier return keylever sets the mechanism into operation. The keylever operates at the right side of the keyboard beside the backspace keylever. The keylever pivots around the fulcrum rod at the rear and operates in the keylever guide comb at the front. The limits of the keylever travel are the same as for the backspace lever. At this point, turn back to figure 9-79.

When the carrier return keylever is depressed, the keylever pawl attached at the rear of the keylever releases the carrier return interposer to the rear. The interposer causes the cam to be engaged and pushes the carrier return operational latch under the cam follower into position to be pulled down. When the cam operates, the cam follower pulls down on the latch. It also pulls down on the index pawl carrier link, attached at the rear of the follower, causing a line space operation. Now, look at figure 9-91. The carrier return operational latch is mounted on the carrier return latch arm that pivots around a shaft on the operational latch bracket at the rear of the powerframe. The shaft is called the pivot pin and also acts as a pivot point for the escapement trigger lever and the spacebar latch lever. Attached solidly to the right end of the pivot pin is a bellcrank called the clutch latch actuating arm. As the cam follower moves the operational latch down, an adjusting screw at the right side of the carrier return latch arm rotates the clutch latch actuating arm and pivot pin.

This action causes three things to occur: (1) the escapement and backspace pawls are removed from their racks, (2) the clutch spring tightens on the hub to drive the carrier return, and (3) the clutch latch actuating arm is latched in the operated position.

The top of the clutch latch actuating arm forces a lug of the escapement torque bar to the rear rotating it to remove the escapement and backspace pawls from their racks. This prevents the pawls from dragging along their racks as the carrier is returned.

The carrier return clutch spring, shown in figure 9-90, tightens around the pinion hub and drives the carrier return operation. Now, in figure 9-92, we see an arm called the carrier return clutch arm The bottom of the clutch arm's pivot pin pulls up on a heavy extension spring. The lower end of the spring is connected to a bellcrank-like part called the carrier return actuating arm. The upward pull on the spring rotates the nylon carrier return shoe (at the top of the arm) against the clutch spring, forcing the spring to tighten and drive the pinion

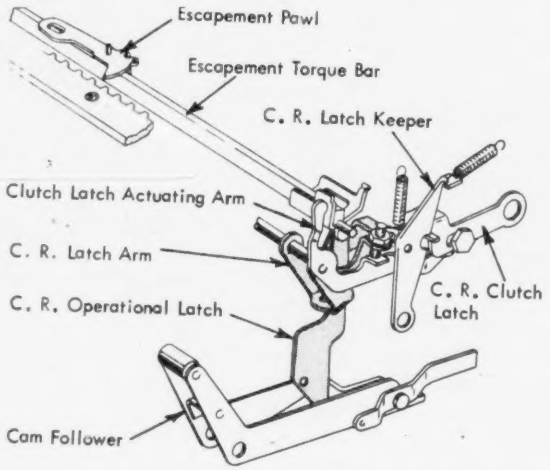


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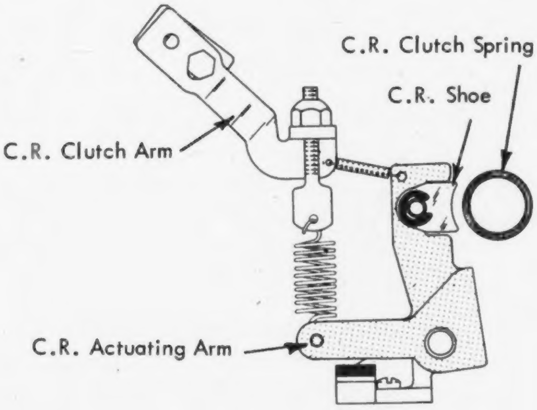
Figure 9-91.—Carrier return latch operation (721).



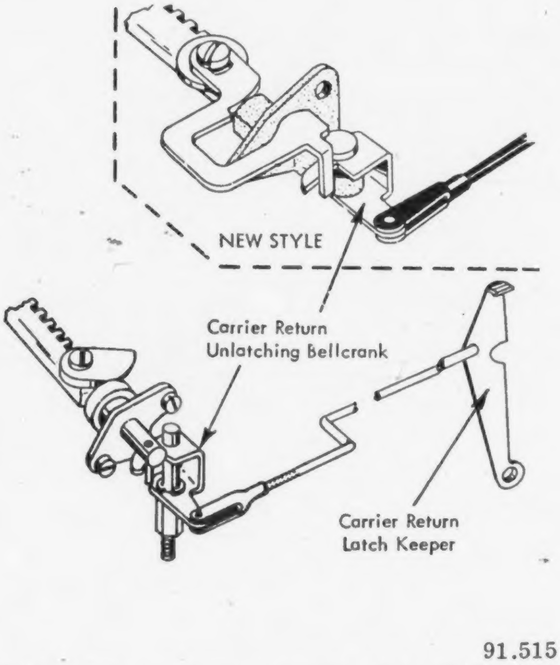
91.514
Figure 9-92.—Carrier return clutch actuating mechanism.

gear. Once the shoe is pressing against the clutch spring, the heavy carrier return actuating spring is extended slightly to maintain a constant pressure against the clutch spring.

The clutch latch actuating arm is latched in the operated position to maintain pawl release and to continue the pressure of the shoe against the clutch spring. The rear of the clutch latch actuating arm contains an elongated hole. An eccentric adjusting screw connects the arm to the carrier return clutch latch, shown in figure 9-91, which pivots at the rear on the powerframe. As the carrier return actuating arm, in figure 9-90, moves down, the clutch latch is also lowered. Spring-loaded against the forward edge of the clutch latch is a hook-like part called the carrier return latch keeper, which is shown in figure 9-91. When the clutch latch has been pulled down into its active position, the keeper hooks over the latch to hold it down. The carrier return mechanism remains latched in the active position until the carrier reaches the left margin. At that time the clutch is unlatched and the escapement pawl is restored to the escapement rack ready for a typing operation.

The margin rack is mounted between the sideframes just in front of the carrier. The margin rack has a small amount of lateral movement. When the carrier is away from the left margin, a spring, located at the left end of the rack, loads the margin rack to the right. As the carrier moves to the left during a return operation, the carrier strikes the left margin stop, forcing the margin rack to the left. The extreme right end of the margin rack contains a roll pin. Movement of the rack to the left causes the pin to operate the carrier return unlatching bellcrank down, as in figure 9-93. A link connects the bellcrank to the carrier return latch keeper at the rear. As the bellcrank operates, the unlatching link pulls the keeper forward, releasing the clutch latch. The latch is restored to the rest position by its spring and the action of the escapement torque bar spring.

Back at figure 9-92, we see that a small spring connected near the carrier return shoe holds the shoe away from the clutch spring in the rest position. The clutch latch does not hold the cam follower in the active position during a return operation; therefore, the cam and follower immediately restores to the rest position ready for the next operation. Depression of the keylever with the carrier in motion releases the interposer to cause another carrier return operation. Because the carrier is already in


NEW STYLE
Carrier Return Unlatching Bellcrank
Carrier Return Latch Keeper

91.515
Figure 9-93.—Carrier return clutch unlatching mechanism.

motion, this amounts to nothing more than another line space operation. Depression of the keylever into the repeat position causes the repeat bail to yield and allows the rear lug of the keylever pawl to release the index interposer to the rear. This causes an index operation only, without operating the carrier return clutch mechanism.

A line space operation can repeat either with the carrier at the left margin or as the carrier is moving toward the left. If the carrier is already resting at the left margin when a carrier return operation begins, the clutch is prevented from latching. The cam is not prevented from latching. The cam is not prevented from operating, however; so a carrier return operation must occur. The platen is indexed, and the carrier return spring clutch attempts to wind the carrier return cord into the drum. The carrier cannot be pulled farther to the left because it is already against the left margin. The pull continues to be exerted on the cord until the cam follower passes the high point of the cam at which time it restores and allows the shoe to move away from the clutch spring.

In figure 9-94 we have a cutaway view and in figure 9-95 an exploded view of the torque limiter. While the cord is being pulled without being able to move the carrier, the carrier return clutch mechanism must be allowed to slip in order to reduce the strain and to prevent breakage to the parts. The carrier return clutch arbor is indirectly driven by the operational shaft. The large shoulder on the arbor fits into a heavy clutch spring at the left called the torque limiter spring. The left end of the spring is clamped to the torque limiter hub, and the torque limiter hub is setscrewed to the operational shaft. The carrier return clutch arbor is then driven by the torque limiter spring. The operational shaft turns in the unwinding direction of the torque limiter spring. This tends to expand it, allowing it to slip. The spring is heavy and considerably smaller than the carrier return clutch arbor over which it fits. The friction present between the arbor and the spring tends to drive the arbor even though it is in the unwinding direction of the spring. However, insufficient driving force is obtained from this arrangement. The right end of the torque limiter spring is formed into an eye to accpet an extension spring connected from the eye to an eccentric adjusting stud on the torque limiter hub. The extension spring increases the force required to unwind the torque limiter spring so that no slippage occurs during normal carrier return. The torque limiter spring slips when the carrier cannot move to the left. It also slips at the beginning of a carrier return operation to allow smooth acceleration and to prevent a jerky start.

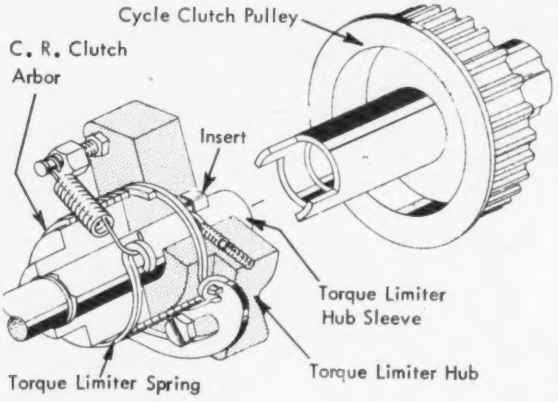


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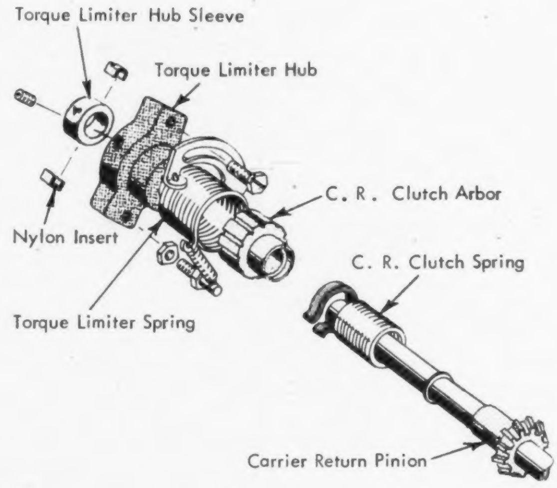
Figure 9-94.—Torque limiter—cutaway view.

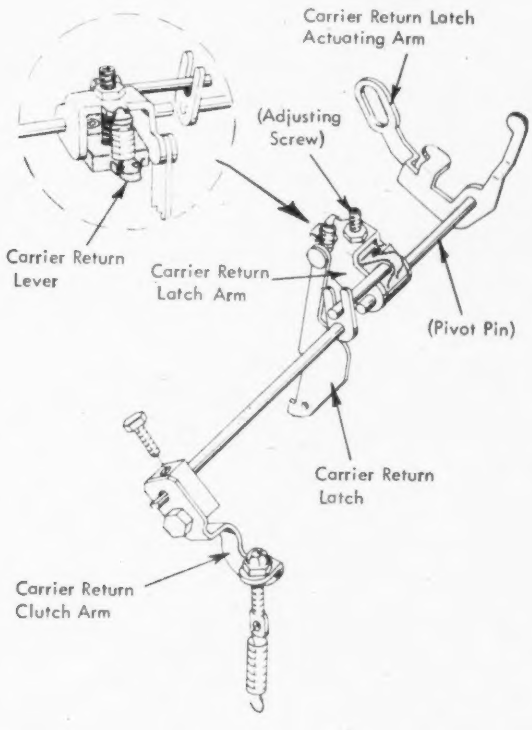


91.517
Figure 9-95.—Torque limiter—exploded view.

CARRIER RETURN (723 and 725).—The operational section of the carrier return mechanism on the long carriage machines (723 and

725) is different from that of the 721 because of the longer carriage. The carriage return operational latch is mounted on the carrier return latch arm, which pivots freely about a pivot pin mounted in the right-hand operational latch bracket at the rear of the powerframe. The carrier return latch arm straddles the carrier return lever, shown in figure 9-96 which is tightly fastened to the same pivot pin by a bristol screw. The bristol screw tightens against a flat spot on the pivot pin. An adjusting screw threaded through the top of the latch arm contacts the top of the horizontal lug on the carrier return lever. A spring between these two pieces loads them together.

When the carrier return latch is pulled down by the cam follower, the latch arm forces down on the carrier return lever causing the pivot pin to rotate. Riveted to the right-hand end of the pivot pin and rotating with it is an arm called the carrier return latch actuating arm. This arm performs the same function on the long carriage machines as it does on the 721. It rotates the escapement torque bar (removing the escapement and backspace pawls from their racks) and also operates the carrier return clutch latch down to its latched position. The carrier return lever has a pin that projects to the left into a forked arm, located on the right-hand end of the carrier return clutch arm pivot pin. This provides a solid driving connection between the two pivot pins. Whenever the carrier return latch is pulled down, the carrier return clutch arm pivot pin rotates, causing the clutch arm to produce a pull on the heavy spring attached to the carrier return actuating arm. From this point on, the operation is the same on long carriage machines as on the model 721.

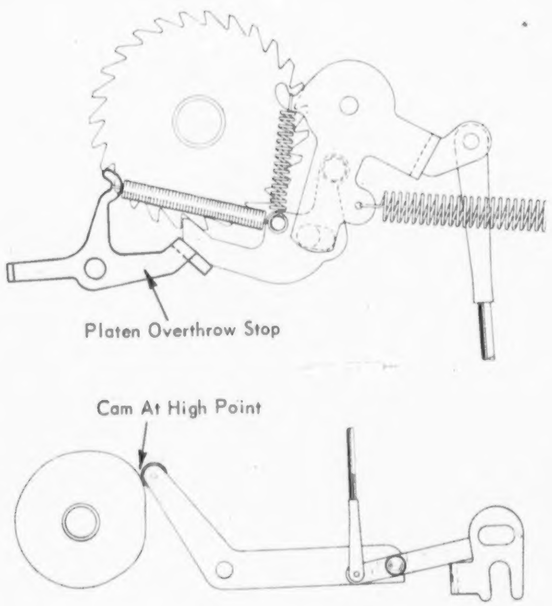


91.518
Figure 9-96.—Carrier return (723 and 725).

INDEXING THE PLATEN VARIABLE

INDEXING.—The indexing mechanism spaces the paper vertically. An indexing operation can be obtained by depressing either the carrier return keylever or the special indexing keylever. Depressing the carrier return keylever also causes the carrier to move to the left margin, whereas depressing the index keylever causes a line space operation only. The index selector lever, located to the rear of the right end of the platen, may be positioned so that the mechanism spaces either one or two spaces during each operation. With the lever forward, single line spacing occurs. Double spacing takes place if the lever is to the rear. Indexing is done by a pawl that engages and rotates a ratchet at the right end of the platen. The ratchet is locked to the platen so that the platen is also rotated. Two styles of indexing mechanisms have been produced.

New Style Indexing.—The new indexing mechanism, shown at the top of figure 9-97 is designed to improve the accuracy and reliability of the indexing operation. It differs from the earlier design mainly in the index pawl and the method of selecting single-or double spacing. In figure 9-98, the index mechanism is in rest position. The index mechanism is operated by the cam follower through the index pawl carrier link connected to the front of the index multiplying lever. The rear of the multiplying lever is always in contact with the multiplying lever stop, which is attached solidly to the powerframe. The top of figure 9-97 shows the indexing mechanism in the active position. As the cam follower operates (as in the bottom part of



91.519
Figure 9-97.—Index mechanism—active position.

fig. 9-97), the multiplying lever pivots on the cam follower and pulls down on the index pawl carrier link shown.

The index pawl carrier link always receives the same amount of motion each time it operates, regardless of whether the mechanism is set for single or double spacing. The amount of travel is sufficient to cause double-space rotation of the platen. During a double-space operation, the index pawl is allowed to enter the platen ratchet immediately. The index pawl then forces the ratchet tooth forward two spaces until the pawl contacts the platen overthrow stop, as seen in the top half of figure 9-97. The overthrow stop wedges the pawl into the ratchet teeth to lock the platen in position. If only a single-space operation is desired, the index pawl must be prevented from entering the ratchet until it has passed one tooth of the ratchet. The remaining travel after the index pawl enters the ratchet is only sufficient to cause a single-space rotation of the platen. The index pawl contacts the platen overthrow stop at the end of the stroke as in a double-space operation.

To see how double spacing it set up, look at figure 9-99. The index pawl entry into the platen ratchet is controlled by the line space cam lever attached to the index selection lever. The cam lever has two steps at the forward end in position to contact a stud on the side of the index pawl. A small spring between the index pawl and the pawl carrier spring-loads the bottom of the pawl toward the platen. With the index selection lever to the rear in the double-space position, the index pawl stud contacts the lower step of the cam, allowing the pawl to rest near the platen ratchet as in figure 9-99.

In the single-space position, the index pawl stud contacts the upper step of the cam lever, causing the index pawl to rest farther from the platen as in figure 9-100. Thus, in the single-space position, the index pawl stud maintains

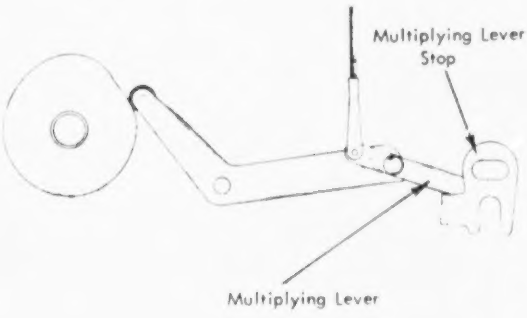


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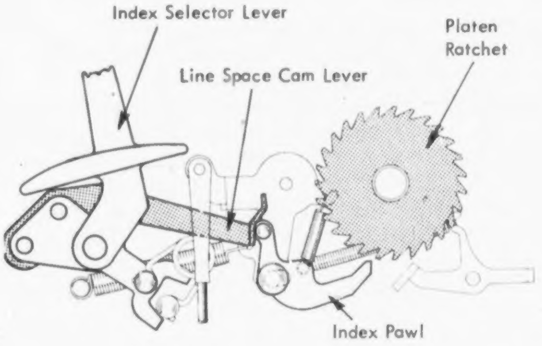
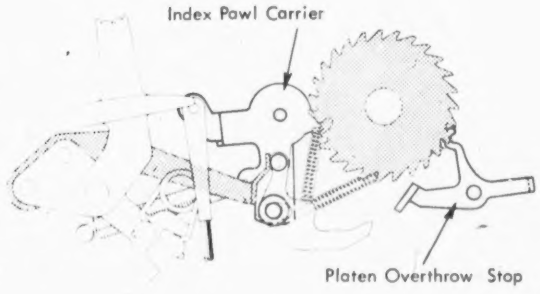
Figure 9-98.—Index mechanism—reset position.



91.521
Figure 9-99.—Index selection mechanism.



91.522
Figure 9-100. — Index selection mechanism.

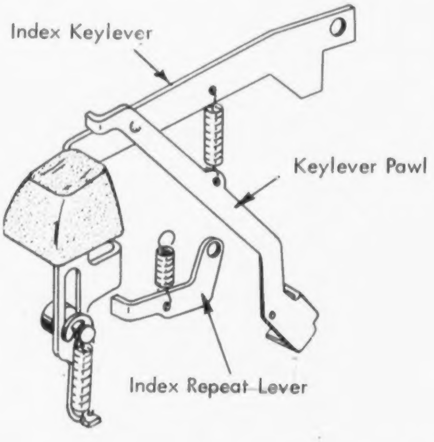
contact with the line space cam lever longer and delays the entry of the pawl into the platen ratchet. The index selection lever is held in the single or double-space position by a toggle hairpin spring. Movement of the index selection lever is restricted by two extensions at the bottom of the lever that contacts the hairpin spring mounting stud.

The index pawl is designed with an elongated pivot hole so that it "floats" forward during a portion of the index stroke. The pawl is spring-loaded forward in the rest position by an extension spring between the pawl and a hook on the platen overthrow stop. A heavier spring between the index pawl carrier and the base tie rod holds the mechanism in the rest position. As the index mechanism operates, the pawl engages the ratchet tooth. There is then a slight delay until the pawl carrier reaches the end of the elongated slot in the index pawl. The pawl carrier is operated so sharply that it actually "kicks" the platen. The platen is thus caused to move ahead of the index stroke. Without the elongated hole in the index pawl, the platen ratchet would reach the final position ahead of the index pawl. With the floating index pawl, the pawl is spring-loaded forward against the ratchet tooth. As the ratchet moves ahead of the index stroke, the pawl is able to move with it and reach the overthrow stop at the same time the platen reaches the final position. The pawl is then able to wedge into the ratchet and block any further rotation due to the momentum of the platen.

INDEX KEYLEVER MECHANISM. — An indexing operation occurs any time the cam operates the cam follower. The cam may be caused to operate by releasing either the index or carrier return interposer to the rear. The carrier return operation has been discussed in another section; therefore, the index alone will be dealt with here.

The index keylever pivots on the keylever fulcrum rod at the rear and extends toward the front only to the first row of keybuttons. An offset in the keylever places the end of the keylever and keybutton outside the right sideframe (see fig. 9-101). A stud in the sideframe fits through an elongated hole in the keylever to limit the overall travel of the keylever. An extension spring from a lug on the keylever to the stud restores the keylever to the rest position. A small spring-loaded arm, called the index repeat lever, operates in a slot in the sideframe under the keylever and acts as a first limit for the keylever depression. When the keylever is depressed to the first limit, the keylever pawl at the rear of the keylever depresses the index interposer to release it to the rear. This releases the cam, allowing the operation to occur. If additional pressure is applied to the keybutton, the index repeat lever yields allowing further depression of the keylever. The rear lug of the keylever pawl then holds the interposer down so that it cannot relatch forward on the guide braket. The interposer continues to operate forward and backward creating a repeat cam operation and a repeat indexing of the platen.

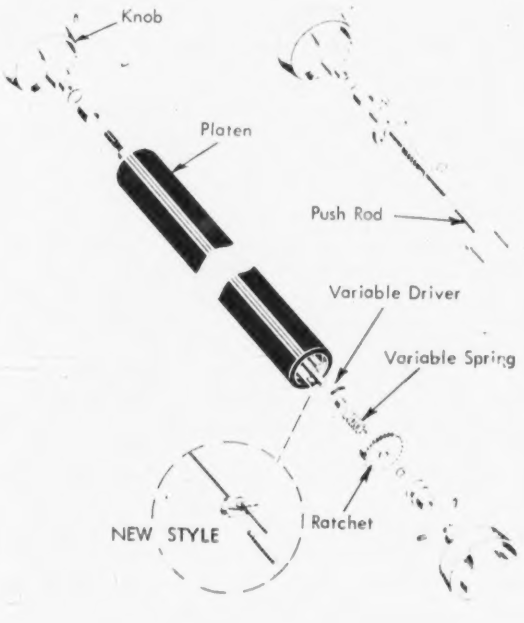
PLATEN VARIABLE. — The platen variable mechanism provides the operator with a means



91.523
Figure 9-101. — Index keylever mechanism.

of rotating the platen to a position other than the normal writing line. The variable is used for typing above or below the writing line, locating the writing line after reinserting the paper, and for typing on lines of other than six-lines-per-inch spacing. The platen ratchet must remain stationary when selecting a new writing line so that the detent roller will be seated between two teeth of the ratchet at the new position. A clutch mechanism connects the ratchet to the platen so that it can be engaged for line spacing and disengaged for the variable operation. The clutch can be disengaged by pushing the left-hand platen knob toward the right. As long as the knob is held to the right, the platen can be rotated freely while the ratchet remains stationary. When the knob is released, the ratchet is automatically reengaged by spring tension.

Notice in figure 9-102 that the left side of the platen ratchet contains two heavy lugs that form a channel. The platen variable driver operates left to right in the slot and always turns with the ratchet. A compression spring between the ratchet and the driver loads the driver to the left so that serrations on the outer surface of the driver mesh with matching serrations inside the platen end plug. The meshing of the serrations causes the platen, the driver, and the ratchet to be locked together and turn as a unit. When the driver is disengaged from the platen end plug, the platen can be turned to the desired position. The driver can then engage different serrations and lock the platen in the new position. The left-hand platen knob is mounted to a shaft that slides left or right inside the platen. A light compression spring holds the shaft toward the right to prevent free play. The shaft has two pins attached to the right end that operate through holes in the platen end plug. The pins on the push rod extend through the end plug to the right and rest against the platen variable driver. Movement of the platen knob toward the right is transferred to the driver to disengage it from the platen end plug.

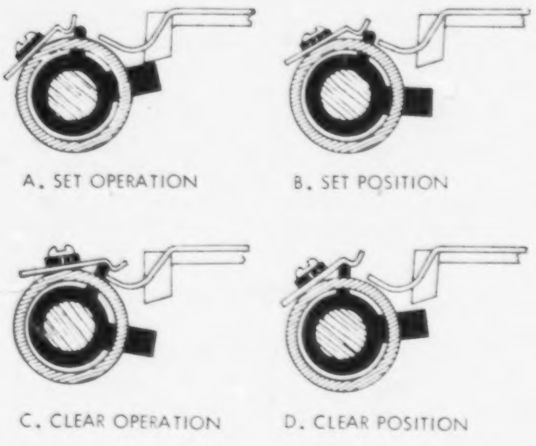


91.524
Figure 9-102.—Platen variable mechanism.

TABULATOR

The tabulator mechanism permits the operator to position the carrier quickly to a predetermined point on the writing line by depressing the tab keybutton one time. The tabulator is used in typing columns on figures, indenting paragraphs, or any other operation that requires positioning the carrier to a specific point each time. In order for a tabulator operation to take place, several basic things must occur. The stopping point must be predetermined. The escapement and backspace pawls must be released to allow carrier movement. The pawls must be latched in the released position to continue the movement. The speed of the carrier must be controlled. And the pawls must be allowed to restore to their racks at the proper time.

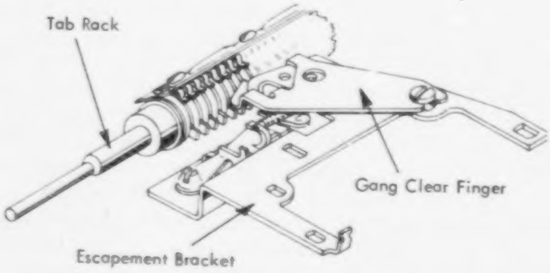
TAB SET AND CLEAR (GANG CLEAR).—Both the tab rack and the tab clear mechanism have been redesigned on late level machines so that the tab stops may be "gang cleared." "Gang clearing tab stops" is the term given to the procedure for clearing all of the set tab stops in one operation. This is done by positioning the carrier at the extreme right-hand margin, depressing the tab clear button, and (while holding the tab clear button depressed) actuating the carrier return mechanism. As the carrier travels toward the left-hand margin, it clears every set tab stop across the entire length of the tab rack. Figure 9-103 illustrates a cross section of the tab rack. Notice that the tab stops encircle and operate freely about a round shaft that runs through the center of the tab rack. The tab rack



91.525
Figure 9-103. — Tab set and clear operation (gang clear).

is a slotted tube that mounts on shouldered bushings setscrewed to each end of the shaft. The slots in the tube are guide slots for each individual tab stop.

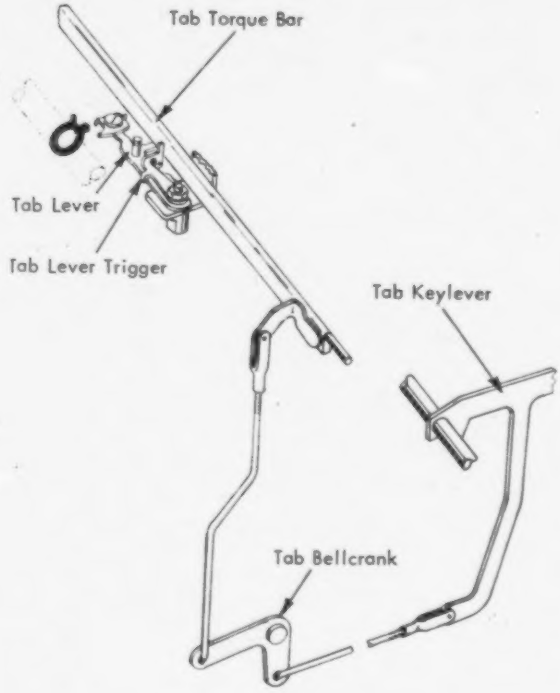
Now, look at figure 9-104. Sections of spring fingers mounted across the entire length of the tab rack operate against small detent lugs (projections) on each tab stop. The spring fingers hold each tab stop in either its set or cleared position. The tab set operation on the gang clear mechanism remains the same as on the old style machine. The tab stop strikes a projection of the escapement bracket, blocking the movement of the tab stop as the tab rack rotates the stop to the rear as in figure 9-103A. The clear operation is slightly different. A gang clear finger, mounted to the top of the escapement bracket and shown in figure 9-104, projects to the rear just below the detent lugs on the tab stops. When the rack rotates the stop to the front during a clear operation, the gang clear finger, which is in the path of the detent lug, restricts the tab stop from rotating with the rack, thereby causing the tab stop to rotate up to its cleared position.



91.526
Figure 9-104. —Gang clear finger.

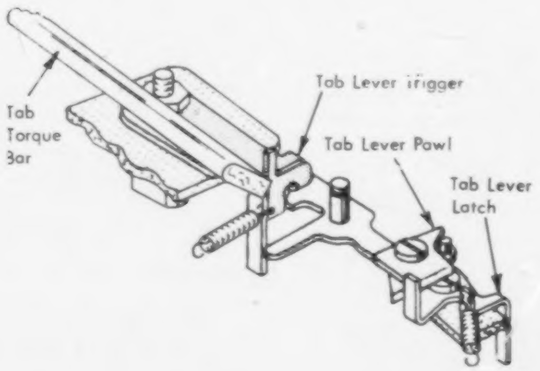
During a gang clear operation, the rack is held rotated in its cleared position as the gang clear finger slides along the rack (with the carrier), camming each set tab stop back to its cleared position. The angle on the left side of the tip of the gang clear finger causes this camming action. The tab rack is restored to rest from either the set or clear operation by an extension spring on the set and clear arm. The spring pulls the arm down against two pins on the powerframe so that it maintains a vertical position. The tab is restored rather quickly when released and has a tendency to flip past the rest position. This could partially clear a stop that had just been set or partially set a stop that had just been cleared. To prevent the rack from restoring past the rest position, a leaf spring at the left end of the rack applies a slight braking action.

PAWL RELEASE. — The main purpose of the tab lever is to remove the backspace and escapement pawls from their racks during a tab operation. The tab lever mounts at the rear of the escapement bracket on the same mounting stud as the backspace and escapement pawls do. The tab lever is very easily operated to the real by a manual process. The tab keylever, shown in figure 9-105, operates at the left side of the keyboard the same as the letter keylevers. A lower extenstion makes the keylever operate as a bellcrank. When the tab keylever is depressed, a link connected to the extension operates the tab bellcrank, located on the powerframe at the rear. Through a vertical connecting link, the bellcrank rotates the tab torque bar. The tab torque bar is mounted in the same way as the escapement torque bar. It pivots at each end and operates just above the tab lever. The pivot point is near the top of the torque bar so that depressing the keylever causes the bottom of the bar to swing to the rear. The tab torque bar contacts a lug of the tab lever trigger located just above the tab lever.

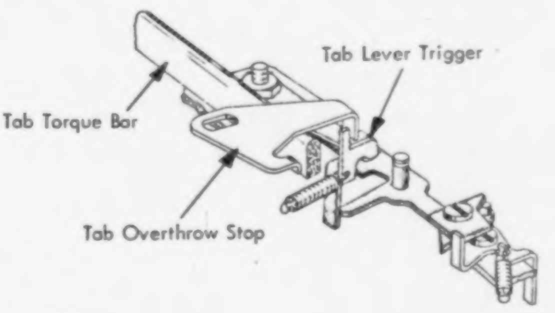


91.527
Figure 9-105.—Tab keylever mechanism.

In figure 9-106, we see that a lower lug of the trigger forces the tab lever to the rear as the keylever is depressed further. As the tab lever pivots toward the rear, a lug at the front of the tab lever contacts the escapement and backspace pawls and forces them to the rear out of mesh with their racks. A small latch pivots on the escapement bracket at the right end of the tab lever. When the tab lever has moved far enough to the rear to release the pawls, the tab latch swings into a notch in the tab lever assembly to hold it to the rear, thus latching the pawls out of their racks. A tab lever overthrow stop is mounted on the escapement bracket. It extends to the rear and down behind the tab lever trigger shown in figure 9-107. The stop prevents the tab lever from being thrown into the tab rack if the keylever is struck hard.



91.528
Figure 9-106.—Tab latch operation.

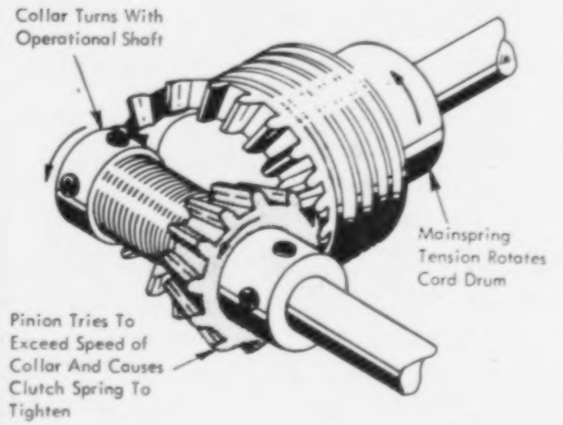


91.529
Figure 9-107.—Tab overthrow stop.

TAB GOVERNOR.—The carrier speed during a tab operation must be controlled to insure an accurate tab, reduce noise, and prevent excessive wear and shock on the components. During a tab operation, the carrier is pulled to the right by the tension of the mainspring as during an escapement operation. The tab governor operates by limiting the speed with which the escapement cord drum winds up the cord.

Look at figure 9-108. The beveled gear on the escapement cord drum meshes with the tab governor pinion, located on the operational shaft to the right of the cord drum. The pinion gear operates between two collars. The left collar and the pinion gear have hubs enclosed by a clutch spring. The left collar is setscrewed to the shaft, and the pinion gear pivots freely on the shaft. The spring is wound so that it slips when the pinion is held stationary and the operational shaft is turning.

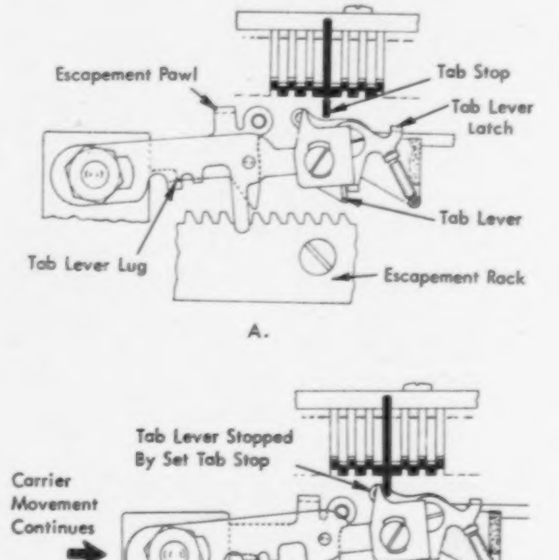
If the pinion gear is turned in the same direction as the operational shaft but at a faster


Collar Turns With Operational Shaft
Mainspring Tension Rotates Cord Drum
Pinion Tries To Exceed Speed of Collar And Causes Clutch Spring To Tighten

91.530
Figure 9-108. — Tab governor mechanism.

rate of speed, the friction of the clutch spring causes it to tighten around the two hubs, locking them together. During a tab operation, the cord drum drives the pinion gear in the same direction as the operational shaft. The mainspring tension causes the pinion to speed up and tighten the clutch spring. The mainspring then tries to accelerate the operational shaft. The mainspring does not have sufficient tension to drive the operational shaft because of the drag present in the system. The shaft must be driven by the motor, therefore the speed of the tab governor pinion can be no faster than the normal speed of the operational shaft. The escapement cord drum can wind up the cord only as fast as the pinion lets it. The gear ratio between the pinion gear and the escapement cord drum allows the carrier to be moved at the proper speed during a tab operation. There is no governing action during approximately the first inch of carrier travel, because a short distance is required to tighten the tab governor clutch spring. The tab governor pinion is the same size as the carrier return pinion gear. This makes the speed of the carrier the same for both tab and carrier return.

TAB UNLATCHING.—When the carrier reaches the desired stopping point, the escapement pawl must be allowed to re-enter the escapement rack and stop the movement of the carrier. The tab lever is mounted in an elongated hole at its pivot point. An extension spring holds the tab lever to the right. As the carrier moves toward the right, the tip of the tab lever contacts the set tab stop and is prevented from moving further, as shown in figure 9-109A.


Escapement Pawl
Tab Stop
Tab Lever Latch
Tab Lever
Tab Lever Lug
Escapement Rack
A.
Tab Lever Stopped By Set Tab Stop
Carrier Movement Continues
Escapement Pawl Released From Tab Lever Lug
Tab Lever Remains Latched
Pawl Enters Rack Teeth
B.
Carrier Movement Continues Until Stopped By The Escapement Pawl
Tab Lever Unlatches And Restores Toward The Fron
C.

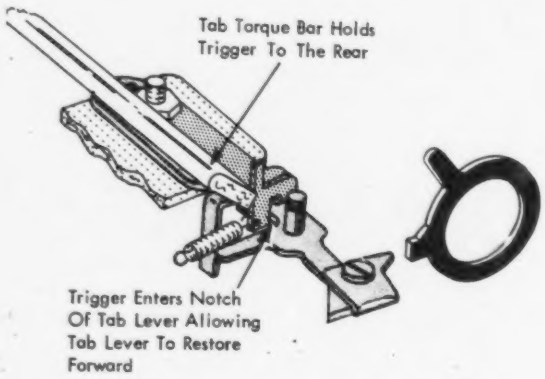
91.531
Figure 9-109. — Tab unlatching operation.

The carrier continues to the right carrying the pawls and the tab latch with it. Movement is allowed by the elongated hole at the tab lever pivot. As the escapement pawl moves to the right in relation to the tab lever, a notch in the pawl allows it to drop off the lug of the tab lever and restore to the escapement rack, illustrated in figure 9-109B. Further movement of the carrier moves the tab latch to the right out of the notch of the tab lever, as shown in figure 9-109C. The tab lever then restores and allows the backspace pawl to re-enter its rack.

The escapement pawl is allowed to enter the rack before the backspace pawl. The escapement pawl must be allowed to enter early to ensure that it enters the correct tooth of the escapement rack. If the backspace pawl were allowed to enter at the same time, the adjustment of the backspace rack could allow the backspace pawl to enter its rack and stop the carrier slightly to the left of the desired point. Delaying the entry of the backspace pawl prevents this.

During a rapid tab/typing operation, it is possible for the typist to delay releasing the tab lever until after a few characters have been typed. If this happened, the carrier could reach the right side of the elongated hole in the tab lever and be stopped by the tab lever against the set tab stop. To prevent blocking the carrier in this manner, the tab lever and tab lever trigger are designed to allow the tab lever to restore, even though the keylever is held depressed. The trigger moves to the right with the carrier during the unlatching travel of the carrier.

Let's look at figure 9-110. At about the same time the tab lever is released by the tab latch, the tab lever trigger moves in front of a notch in the tab lever. The tab lever is then allowed to move forward into the rest position. The tab lever is restored by the action of the spring on the tab lever and the backspace pawl. When the tab lever trigger restores, the tab lever is allowed to reset for the next operation. As the trigger moves out of the notch in the tab lever, the tab lever is snapped to the right by its spring into position to be operated by the trigger. At the same time, the tab lever lug resets to the right in front of the escapement pawl ready for pawl release on the next operation. A forward extension of the tab lever rests against the escapement bracket. A lug at the rear of the tab lever trigger resets against the tab lever to prevent the trigger from resting against the tab torque bar. Improper rest position of the tab lever can cause backspace problems if the backspace pawl is not allowed to mesh deeply enough into its rack. The tab lever will also fail to reset to the right in front of the escapement pawl if the tab lever rests too far to the rear. The tab mechanism would then be inoperative, because no pawl release could be obtained.

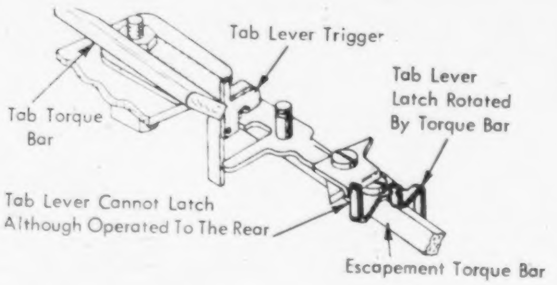

Tab Torque Bar Holds Trigger To The Rear
Trigger Enters Notch Of Tab Lever Allowing Tab Lever To Restore Forward

91.532

Figure 9-110.—Tab lever trigger operation.

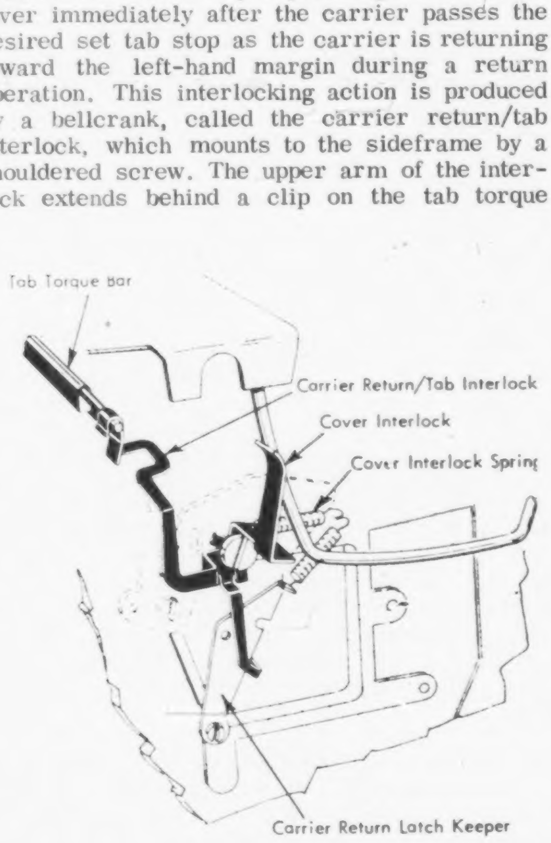
TAB INTERLOCK.—Study figure 9-111 to see how the tab lever is prevented from latching to the rear during a carrier return operation. If the tab lever were allowed to latch, the tab lever pawl attached to the end of the tab lever would strike the right side of a tab stop, locking the carrier. The tab lever is prevented from latching by restricting the tab latch from rotating into its latching position. A lug at the rear of the tab latch extends down behind the escapement torque bar. Whenever the escapement torque bar is operated, as during a carrier return, the tab latch is rotated counterclockwise away from the tab lever. Thus, the tab lever cannot latch.

CARRIER RETURN/INTERLOCK.—The drawing in figure 9-112 shows that the carrier return/tab interlock allows a tab operation to supersede or unlatch a carrier return operation. An operator can use this interlock feature to obtain a partial carrier return that will be followed by a tabulation operation to a desired set tab stop. This gives the operator a helpful


Tab Lever Trigger
Tab Lever Latch Rotated By Torque Bar
Tab Torque Bar
Tab Lever Cannot Latch Although Operated To The Rear
Escapement Torque Bar

91.533
Figure 9-111.—Carrier return tab interlock.

shortcut when typing a column of figures or listing at the right side of the paper. The operation is achieved by depressing the tab keylever immediately after the carrier passes the desired set tab stop as the carrier is returning toward the left-hand margin during a return operation. This interlocking action is produced by a bellcrank, called the carrier return/tab interlock, which mounts to the sideframe by a shouldered screw. The upper arm of the interlock extends behind a clip on the tab torque bar while the lower arm extends behind the carrier return latch keeper. When the tab torque bar is rotated, it pushes on the upper arm of the interlock, causing the lower arm to pull the keeper forward and unlatch the carrier return. The additional arm mounted on the same shouldered screw is for interlocking the carrier return whenever the top cover is raised. This is a "safety" interlock.

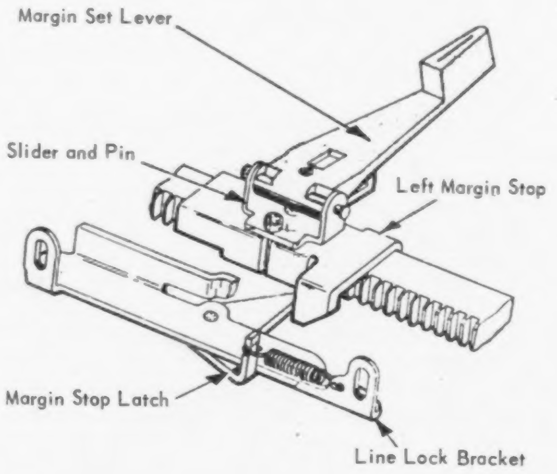

Tab Torque Bar
Carrier Return/Tab Interlock
Cover Interlock
Cover Interlock Spring
Carrier Return Latch Keeper

91.534
Figure 9-112.—Carrier return/tab interlock.

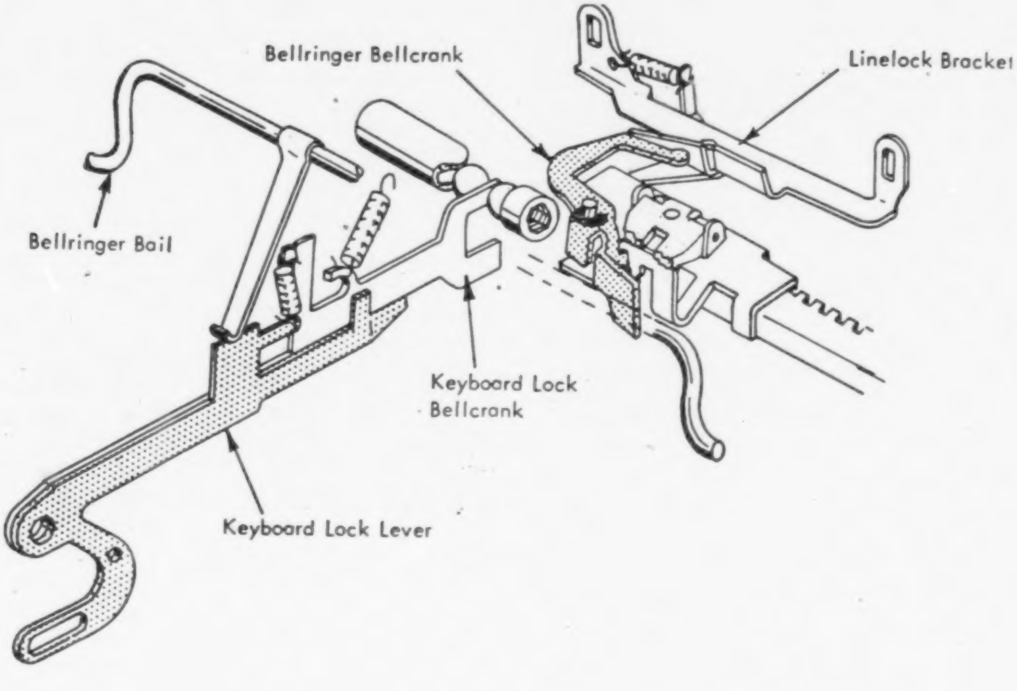
MARGIN CONTROL

The term "margin" denotes the distance between the edge of the paper and the typewritten material. The left and right margins are determined by the position of the margin stops on the margin rack. The carrier travel is restricted by contacting the margin stops.

MARGIN STOP.—Look at the left margin release mechanism in figure 9-113. The margin stops are mounted on the margin rack. The rack is positioned horizontally in the machine in front of the carrier. Each margin stop has a slider and pin assembly that meshes with teeth at the rear of the margin rack. The number of teeth per inch in the margin rack corresponds to the pitch of the machine. Each margin stop has a margin set lever attached to the slider and pin assembly. The margin set levers extend through a slot in the front case so as to be accessible to the


Margin Set Lever
Slider and Pin
Left Margin Stop
Margin Stop Latch
Line Lock Bracket

91.535
Figure 9-113.—Left margin mechanism.



91.536

Figure 9-114.—Line lock mechanism (new style).

operator. Either margin stop may be repositioned by pushing the margin set lever to the rear to disengage the pin from the rack and then sliding the margin stop along the rack to the desired location. A scribe line on the margin set lever acts as a pointer to indicate the position of the margin stop in relation to the scale on the front of the case. A pointer on the front of the carrier indicates the position of the carrier. The left-hand margin stop controls the left margin on the paper. An extension of the stop is struck by the margin stop latch pivoted on a bracket attached to the carrier. This action forces the margin rack to the left to unlatch the carrier return, leaving the carrier resting at the left margin position.

LINE LOCK (NEW STYLE).—On the new style line lock mechanism, the keyboard lock interposer and its operation have been eliminated. It has been found that the operation of the bellringer bail can put enough spring tension on the keyboard lock bell crank to snap the bellcrank into the compensator tube at the earliest possible instant. The keyboard may still lock one space later after the carrier reaches the right-hand margin because of the character storage feature. The drawing in figure 9-114 shows that the line lock consists of two pieces, the keyboard lock lever and the keyboard lock bellcrank, the bellringer bail operates the keyboard lock lever down (as the carrier approaches the right-hand margin), causing the keyboard lock bellcrank to be moved into the selector compensator tube by the tension of the spring between the lever and the bellcrank.

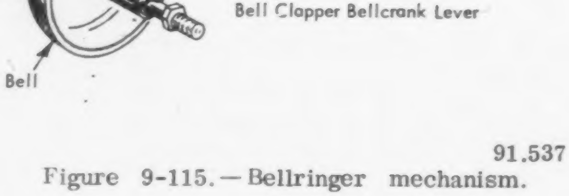
Note in figure 9-114 that the bellcrank is one piece. The new style helps to reduce lost motion between the line lock bracket and the bellringer bail. Because of this new style bellringer bellcrank, the entire margin rack must tip each time the carrier is returned through the right-hand margin. The rear extension of the bellcrank must ride up and over the camming surface on the line lock bracket, causing the margin rack to rotate too. The line lock bracket assembly has also been redesigned to simplify the margin release operation at the left margin. The mounting hole in the margin stop latch has been elongated. This allows the stop latch to float to the left under its restoring spring tension whenever the margin release is operated while the carrier is against the left-hand margin stop. This eliminates the necessity of holding the margin release button depressed until the carrier is moved to the left.

BELL.—Consult figure 9-115. The bell is located on the left side of the keyboard section and is rung by the bell clapper attached to a bellcrank above the bell. The bell clapper bellcrank is operated by the action of the bellringer bail, located across the machine just in front of the margin rack. The bellringer bellcrank, pivoted on the right margin stop, is contacted by the line lock bracket attached to the front of the carrier. As the carrier moves to the right, the bellcrank pivots, causing the bellringer bail to rotate forward. A small lever at the left end of the bail moves the bell clapper into the active position. Further rotation of the bail causes the bail lever to slip off the bell clapper bellcrank, allowing it to restore. An arm of the bellcrank contacts the bell mounting stud, causing the bellcrank to stop suddenly. The momentum of the bell clapper causes it to spring over and strike the bell one time. When the bellringer bail is allowed to restore, the bail lever resets above the bell clapper bellcrank ready for the next operation.

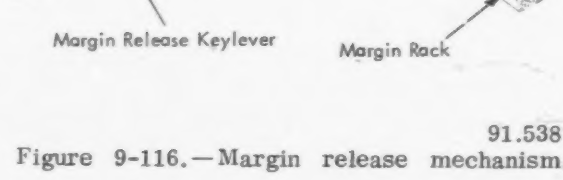
MARGIN RELEASE.—The purpose of the margin release mechanism is to allow typing on either margin of the paper without repositioning the margin stops. The margin release operates by rotating the margin rack so that the margin stops move upward out of the path of the line lock bracket on the carrier. The margin release keylever, figure 9-116 pivots at the left side of the keyboard. A stud at the rear of the keylever operates in a slot in the margin release lever. The margin release lever is attached to the margin rack. Depression of the keylever causes the margin release lever to be raised. This action rotates the margin rack, raising the rear of the margin stops. A lug on the left end of the margin rack remains in the path of the carrier to unlatch the carrier return if it is operated with the margin release keylever depressed. An extension spring from the keylever down to a lug on the keyboard sideframe restores the mechanism and holds it in the rest position.

PAPER FEED AND RELEASE MECHANISMS

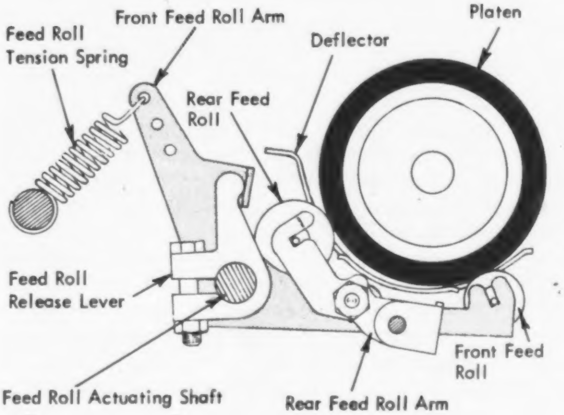
PAPER FEED.—The purpose of the paper feed mechanism is to control both the horizontal and the vertical positions of the paper in the machine and to feed the paper vertically. A study of the drawing in figure 9-117 will help you to remember that the paper feed operates by pressing the paper tightly against the platen so that it must move as the platen rotates. The



91.537
Figure 9-115.—Bellringer mechanism.



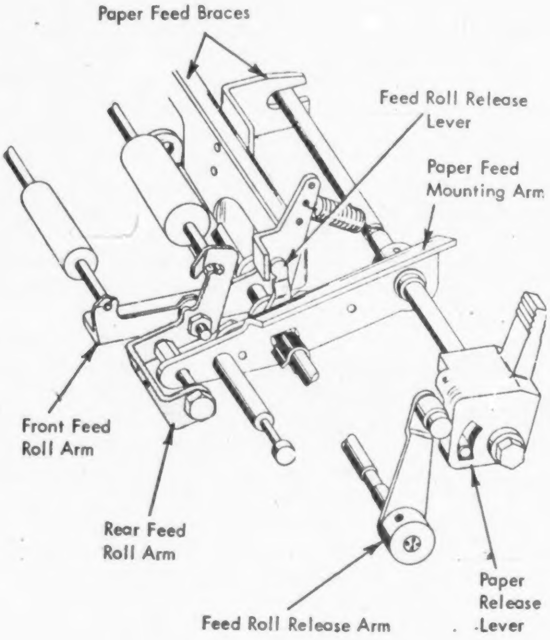
91.538
Figure 9-116.—Margin release mechanism.


Feed Roll Tension Spring
Front Feed Roll Arm
Rear Feed Roll
Deflector
Platen
Feed Roll Release Lever
Front Feed Roll
Feed Roll Actuating Shaft
Rear Feed Roll Arm

91.539
Figure 9-117.—Paper feed mechanism.

paper is held against the platen by a front and rear feed roll assembly, located beneath the platen. Each feed roll assembly contains four rubber rollers equally spaced along the feed roll shaft and molded to the shaft. The front feed roll shaft rests in notches of the front feed roll arms. The front feed roll arms pivot on the feed roll actuating shaft. A heavy extension spring from each front feed roll arm to the carriage tie rod supplies the pressure of the front feed roll against the platen. Various holes in the feed roll arms provide a means of adjusting the pressure.

PAPER RELEASE.—Our drawing in figure 9-118 indicates that the pressure of the front and rear feed rolls is released from the platen to allow the operator to position the paper more accurately and allow easier insertion and removal of the paper. The paper is released by pulling forward on the paper release lever, located at the right end of the carriage. The front of the paper release lever cams the top of the feed roll release arm forward to rotate the feed roll actuating shaft. Two feed roll release levers are clamped to the feed roll actuating shaft and rest behind a lug of each front feed roll arm. As the shaft rotates, the feed roll release levers rotate the front feed roll arms down, away from the platen. The rear feed roll arms are, in turn, forced away from the platen by their connection to the front feed roll arms. When the paper release lever has been pulled all the way forward, the end of the feed roll release arm snaps over the point at the front of the paper release lever to hold it in the release position.


Paper Feed Braces
Feed Roll Release Lever
Paper Feed Mounting Arm
Front Feed Roll Arm
Rear Feed Roll Arm
Feed Roll Release Arm
Paper Release Lever

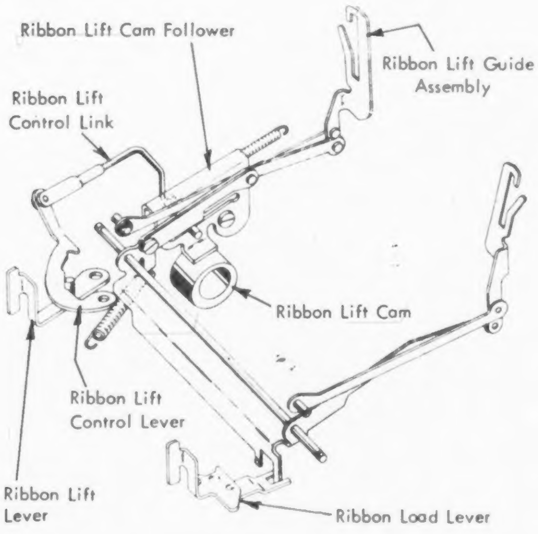
91.540
Figure 9-118.—Paper release mechanism.

FABRIC RIBBON

The ribbon mechanism is divided into two separate and distinct mechanisms. They are the ribbon lift mechanism and the ribbon feed and reverse mechanism. The ribbon lift mechanism raises the ribbon to the printing point before the type head prints and then lowers it to allow a visible writing line. The feed and reverse mechanism moves the ribbon laterally past the printing point to provide an unused portion for the next typing operation. It also reverses the feeding direction when the end of the ribbon is reached.

The ribbon is a 9/16-inch fabric ribbon inclosed in a disposable cartridge unit for clean handling. The cartridge unit contains two spools on which the ribbon is wound. The ribbon is constantly fed from one spool to the other and back again until the ink supply has been depleted. Replacing the ribbon is a clean, effortless operation. Located to the right of the pointer on the carrier assembly is the ribbon load lever. A drawing of the lift mechanism is shown in figure 9-119. When pushed to the right the load lever forces the ribbon lift guide into an extreme lift position for accessibility. The ribbon load lever holds the ribbon lift guide in the high lift position. The cartridge can be removed from the ribbon feed plate by simply lifting it off. The ribbon can then be easily removed from the guide without touching the ribbon.

Installing a new ribbon is just the reverse of the above. With the ribbon lift guide still in the extreme lift position, the ribbon can be inserted into the guide and the cartridge snapped into place all in one motion. Tapered lugs on the sides of the ribbon feed ratchet cores automatically guide the ribbon spools into the correct position. Guide lugs at each side of the feed plate maintain the lateral position of the cartridge. Retainer springs attached to the guide lugs hold the cartridge down to prevent vibration. After the ribbon is installed, the load lever is moved back to the left to allow the ribbon lift guide to restore to its normal position ready for a typing operation.



91.541
Figure 9-119.—Ribbon lift mechanism.

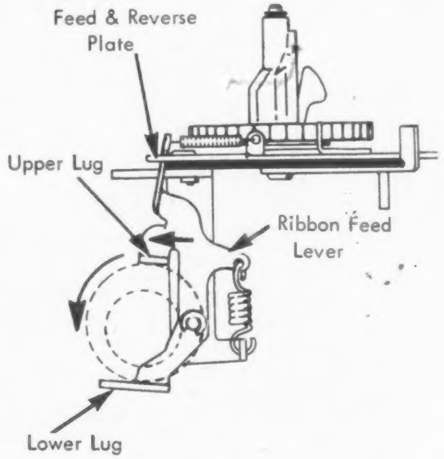
RIBBON LIFT.—Still referring to figure 9-119 we see that the ribbon lift mechanism consists of a cam, cam follower, control mechanism, and the ribbon lift guide assembly. The mechanism is mounted to the carrier assembly and is transported by the carrier along with the type head. The ribbon lift cam is a single-lobed cam setscrewed to the left end of the print sleeve. The cam has a punchmark on the right side that must line up with the print sleeve key-way to insure that the cam is not out of time with the print operation. If you replace the cam, make sure that you do not install it in a reversed position.

The cam makes one complete revolution each time a cycle operation occurs. The ribbon lift cam follower pivots on the carrier casting above and to the rear of the cam. Each operation of the cam raises the cam follower. The cam follower contains a long slot. In the slot is the end of the ribbon lift control link. The ribbon lift guide assembly rests directly above the control link. As the cam follower is raised, the control link forces up on the ribbon lift guide assembly. The guide assembly pivots on the carrier casting at the front, causing the ribbon to be raised at the rear. A flat link from each side of the ribbon lift guide attaches to two pins at the front of the carrier to maintain the ribbon lift guide in a vertical position.

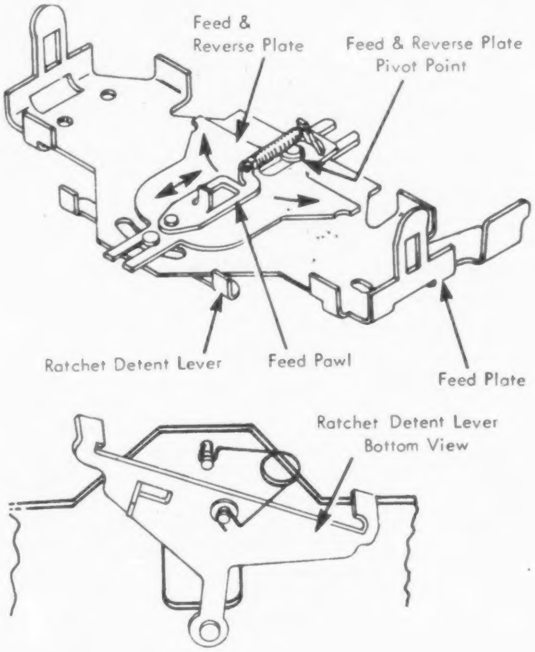
The height to which the ribbon is raised is determined by the position of the ribbon lift control link in the slot of the cam follower. When the link is in the extreme rear of the slot, very little motion is obtained from the cam follower; consequently the ribbon lift guide is not raised at all. This is called the stencil position. As the ribbon lift control link is moved toward the front in the slot, more and more motion is obtained from the cam follower. The link is also moved near the pivot point of the ribbon lift guide assembly so that the motion obtained from the follower is more effective in raising the ribbon. The nearer to the front the link is moved, the higher the ribbon is raised. In addition to the stencil position there are three ribbon lift positions which may be selected by the operator.

The ribbon lift control link is attached to the ribbon lift control lever pivoted under the front of the carrier casting. The control lever is spring-loaded to the rear against a stud on the ribbon lift lever. The ribbon lift lever has a button located just to the left of the carrier pointer. Moving the button to the left causes the stud on the lever to force the ribbon lift control lever and link toward the front. The stud of the ribbon lift lever seats into notches in the control lever to maintain its position until changed by the operator. The extreme right-hand position of the button is the stencil position, where no ribbon lift is available. The next position to the left is the low lift position used for typing on the top half of the ribbon. The third position allows typing in the middle of a single colored ribbon. The extreme left position of the button is the high lift position and is used for typing on the bottom half of the ribbon. The ribbon lift guide assembly is spring-loaded into the rest position to insure that it will restore rapidly. The spring loading also prevents overthrow of the ribbon due to the momentum of the lift mechanism.

RIBBON FEED. — The motion for a feed operation is provided by a cam on the print sleeve called the ribbon feed and detent cam. As the cam rotates during a print cycle, it causes a cam follower called the ribbon feed lever to pivot in the counterclockwise direction about its mounting stud fig. 9-120. The ribbon feed lever is C-clipped to its mounting stud which is located on a heavy vertical support riveted to the underside of the ribbon feed plate. An extension spring fastened to the feed lever and anchored to the support loads the lever in a clockwise direction, causing the lower lug to ride against the cam throughout a feed operation fig 9-120. The reason for the upper lug will be explained in the reverse operation. As the ribbon feed lever is rotated in the counterclockwise direction by the cam, its upper extension, which projects through a window in the feed and reversing plate, slides the plate toward the rear fig. 9-120. The feed and reverse plate is mounted on the top side of the ribbon feed plate in a manner that permits it to slide back and forth with each revolution of the cam. A shouldered rivet anchored to the feed plate passes through an elongated slot in the feed and reverse plate fig. 9-121. This rivet acts as a guide for the rear of the plate as it operates back and forth. The front of the plate is secured and guided by a recessed pin that is riveted to a part of the reversing mechanism called the "ratchet detent lever" fig. 9-121. The back and forth movement of the feed and reverse plate is transmitted to the ratchet teeth of a ribbon feed ratchet by a feed pawl. This pawl is attached to the feed and reverse plate by a shouldered rivet. An extension spring anchored to the vertical lug of the ribbon



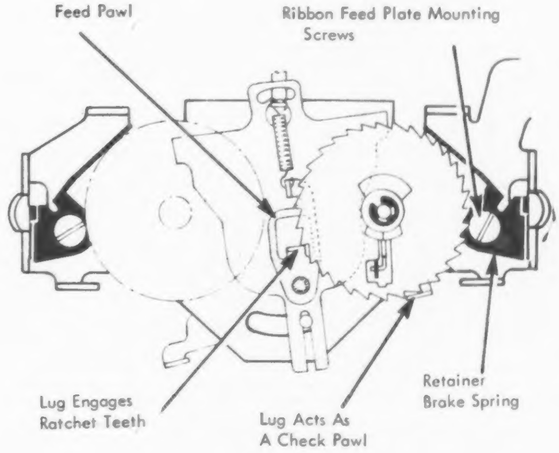
91.542
Figure 9-120.—Ribbon feed lever beginning of feed operation).


Feed & Reverse Plate
Feed & Reverse Plate Pivot Point
Ratchet Detent Lever
Feed Pawl
Feed Plate
Ratchet Detent Lever Bottom View

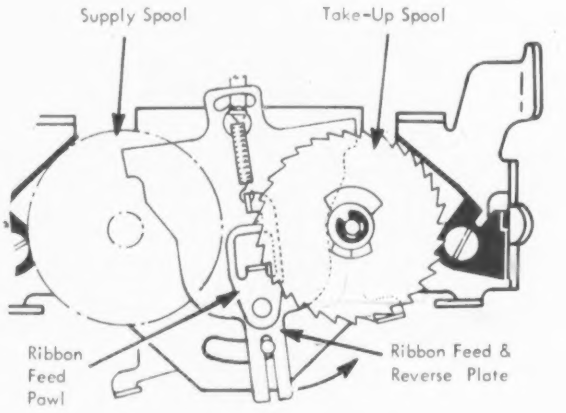
91.543
Figure 9-121.—Ribbon feed and reverse plate mounting.

feed lever loads the feed pawl into engagement with the ratchet teeth fig. 9-122. Each time the feed cam makes one revolution, the feed pawl will drive the ribbon feed ratchet approximately 2-1/2 teeth. The timing of the cam causes the ribbon feed action to occur early in the print cycle. At the time the typehead prints, the ribbon has completed its feeding operation except for the restoring of the feed pawl. As the feed pawl restores to the front, it slides along the teeth into its rest position. The drag of the pawl over the ratchet teeth tends to rotate the ribbon feed ratchet backwards, thus, unwinding the ribbon. To prevent this from occurring a lug on the ratchet detent lever is spring-loaded into the ratchet teeth fig. 9-122. This lug acts as a check pawl. Since feed is not a smooth operation but occurs in a series of jerks, the ribbon spool that is acting as a supply spool would tend to over-spin or "spool off" between feed operations unless a drag or braking action were placed unpon it. This necessary drag is provided by placing a leaf-type spring against the ratchet teeth of the ribbon feed ratchet. This leaf is an extension of the retainer/brake spring which also functions as a clamping device for the ribbon cartridge. Both retainer/brake springs are held in place on top of the ribbon feed plate by the same screws that mount the feed plate to the carrier fig. 9-122.

RIBBON REVERSE. — The ribbon is fed from the supply spool onto the take-up spool until the supply spool becomes empty fig. 9-123. At this time, the process must be reversed; that is, the "empty" supply spool becomes the take-up spool and the "full" take-up spool becomes the supply spool. To achieve this reversing process, it is merely necessary to shift the ribbon feed pawl to the ribbon feed ratchet that contains the empty spool. Since the feed pawl is riveted to the feed and reverse plate, the reversing operation is accomplished by shifting the front of the feed and reverse plate to either the left or right depending on which spool is empty figure 9-124. A small bellcrank mounted in the core of each ribbon feed ratchet acts as a sensing device to determine when the reversing operation is to take place. As long as there is ribbon wrapped around the core of the supply spool, the ribbon will hold this bellcrank called the reverse trigger in its inactive position. Once the last loop of ribbon is pulled off the supply spool core, a spring finger causes the reverse trigger to pivot out of the core. This action causes the lower portion of the trigger to protrude below the bottom surface of the ribbon feed ratchet fig. 9-125. The reverse trigger actually drops down and rides on the top surface of the ribbon feed plate. As the ribbon continues to feed, the almost empty spool rotates slightly further. This causes the lower extension of the reverse trigger to swing into the path of a notch in the feed and reverse plate as the plate is operating back and forth during the feed operation. On the forward or restoring stroke of the plate, the reverse trigger restricts one side of the



91.544
Figure 9-122. — Feed pawl and ratchet checking.



91.545
Figure 9-123. — Right hand ratchet driver.

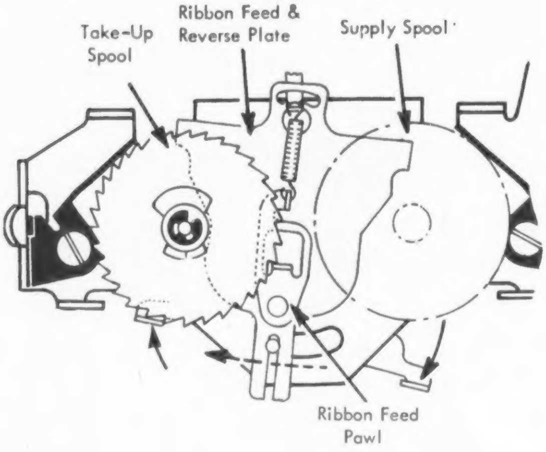
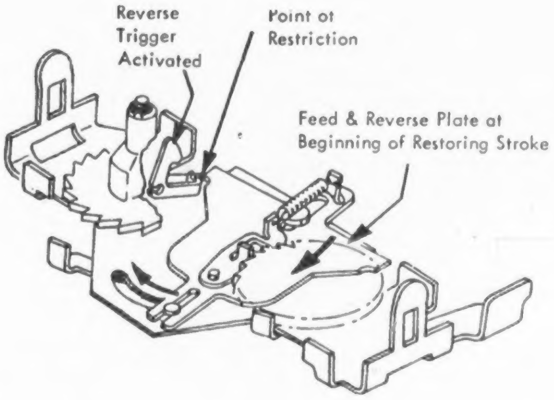
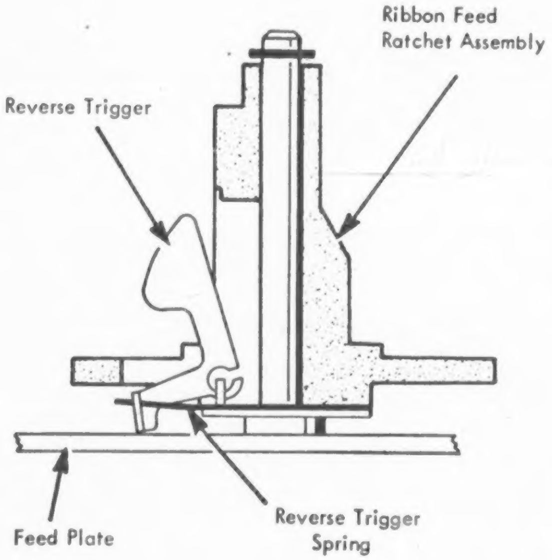

Take-Up Spool
Ribbon Feed & Reverse Plate
Supply Spool
Ribbon Feed Pawl

Figure 9-124.—Ribbon feed transferred to L. H. ratchet. 91.546


Reverse Trigger Activated
Point of Restriction
Feed & Reverse Plate at Beginning of Restoring Stroke

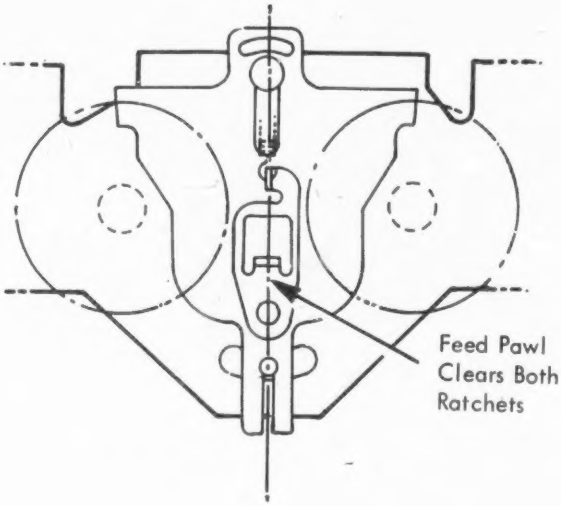
91.548
Figure 9-126.—Reverse action.

plate from sliding forward fig. 9-126. The other side continues to slide forward, thereby causing a pivoting action to the entire plate about the point of restriction. This makes the front of the plate swing towards the opposite side, positioning the feed pawl in line with the ratchet teeth of the ribbon feed ratchet containing the empty ribbon spool.


Ribbon Feed Ratchet Assembly
Reverse Trigger
Feed Plate
Reverse Trigger Spring

91.547
Figure 9-125.—Reverse trigger (activated).

The next feed stroke, the feed pawl will engage the ratchet teeth of the empty spool, causing it to begin to take on ribbon. Thus, the reversing operation is accomplished. When you read the explanation of ribbon feed, you found that is was necessary to restrict the ribbon feed ratchet from being dragged backwards by the feed pawl during the restoring portion of a feed cycle. This is accomplished by a ratchet detent lever that is spring loaded into engagement with the teeth of whichever ribbon feed ratchet is operating as the "take up" spool. Since the reversing action makes the "full" take up spool become the supply spool and the "empty" supply spool become the take up spool, it is necessary to disengage the ratchet detent lever from one feed ratchet and engage it with the other. This is done in step with the reversing operation. As the front of the feed and reverse plate swings, causing the feed pawl to engage with the opposite feed ratchet, it pivots the ratchet detent lever to the opposite spool. A stud riveted to the lever protrudes up through a slot in the feed and reversing plate linking the two together. A hairpin spring fastened to this stud and anchored to the feed plate provides a toggling action to both the feed and reverse plate and the ratchet detent lever. In addition, the hairpin spring keeps the ratchet detent lever constantly spring loaded against the teeth of the feeding ratchet. Assurance of a positive reverse operation is dependent entirely upon the ribbon feed lever



91.549
Figure 9-127.—Ribbon feed pawl (no feed position).

following the ribbon feed cam back to rest. During a reverse operation, the extension spring which loads the lower lug of the ribbon feed lever against the feed cam might not be strong enough to keep it against the cam during the restoring portion of the feed cycle. If this should occur, the upper lug fig. 9-120 on the feed lever will come in contact with the cam causing the feed lever to be powered back to rest. Therefore, this upper lug assures that the reversing operation is a powered operation and not dependent upon the action of an extension spring.

STENCIL LOCKOUT.—Ribbon feed is interrupted during the stencil mode of operation. This is done by centering the feed pawl between the ratchet spools so it can move freely back and forth without engaging a ratchet tooth fig. 9-127. The feed pawl is caused to operate in this manner by the ribbon lift lever when it is in the no lift or stencil position. Two lugs on the ribbon lift lever form a "V" which trap a lug on the ratchet detent lever fig. 9-128. As the ribbon lift lever is placed in the stencil position, one or the other of the lugs, depending upon which spool is being driven, will contact the lug on the ratchet detent lever and cam it

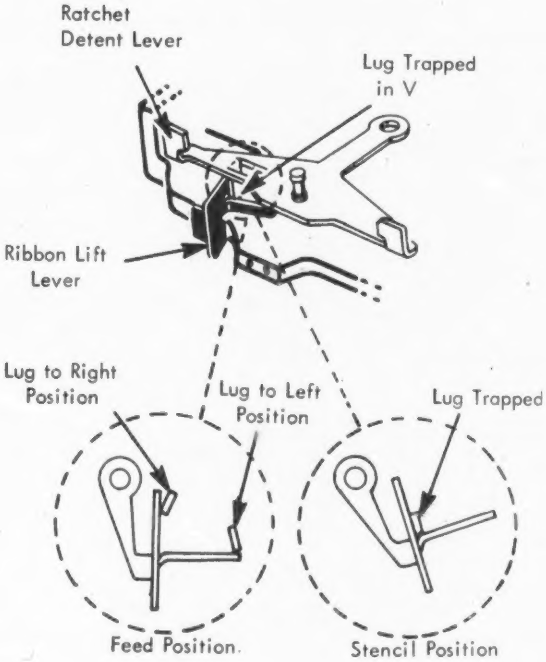


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Figure 9-128.—Stencil lockout.

to the center of the "V" fig. 9-128. At this point, the ribbon lift lever will be in a detented position and the ratchet detent lever will be centered. With the ratchet detent lever in this position, the feed pawl will be guided between the ratchet spools.

CLEANING OF THE IBM SELECTRIC

An IBM Selectric should be blown out with air pressure not to exceed 40 psi, 15 psi is an ideal pressure to use to remove loose eraser particles, dust, dirt, and paper fragments.

When an IBM Selectric is gummy, with dried caked on dirt, or has had some foreign substance (coffee, coke, or the like) spilled in it and has to be cleaned furtner, disassemble; removing all rubber parts and electrical components Then clean as you would any other electric typewriter, using either agitator, dip or ultrasonic cleaner. When a solvent is to be used, first clean machine with an industrial speed soap, using Varsol dip as a drying agent. After cleaning, lubricate machine, removing all excessive lubricant. Light instrument oil can be used to lubricate, using a pickup nozzle and air gun to spray oil through machine. Blow all excess oil off of parts. On bearing surfaces use light grease, sparingly. Special lubricants, for each section of the machine, are available from IBM Corporation.

CHAPTER 10

CALCULATORS

You hear a lot about computers these days - computers in industry, in space vehicles, and in ships. The computers that contribute so much to modern technology share many characteristics with the adding machine and calculator. In this chapter you will learn how the mechanical calculator works, and how to perform maintenance on this type of machine.

There are two basic types of mechanical calculators; the printing calculator and the dial calculator. The printing calculator is a relatively new design which is a refinement of the mechanical systems used in the dial calcualtor. The dial calculator offers several advantages for the type of work it is used for in the Navy. Its principal advantage is that it can handle much larger figures than most printing calculators can. The dial calculator shows the answer to a problem on a set of dials on the calculator carriage. As you can see in figure 10-1, eleven digits can be displayed on the upper dial, and twenty on the middle dial. Most dial calculators are similar to the one shown. Numerical data is entered on the keyboard, and is transferred to one of the two sets of dials by means of levers and gears. In solving a problem, the machine adds or subtracts from the total shown on the dials.

Printing calculators differ from dial calculators in that keyboard entries are transferred to a typing mechanism which prints the entries to show not only the solution to a problem, but also records the steps followed to obtain the answer.

As an IM1 or IMC, you are expected to be able to test a calculator and to adjust and repair it to correct common malfunctions. This chapter describes the various mechanisms of the Marchant Figuremaster Calculator whose operating principles are typical of a number of other dial calculators. When you have learned the material in this chapter, you will be able to perform routine maintenance on the Marchant calculator, and to analyze and correct malfunctions in this machine. With this knowledge, you will be able to maintain and repair similar machines with the aid of the appropriate manufacturer's technical manuals.

THE MARCHANT CALCULATOR

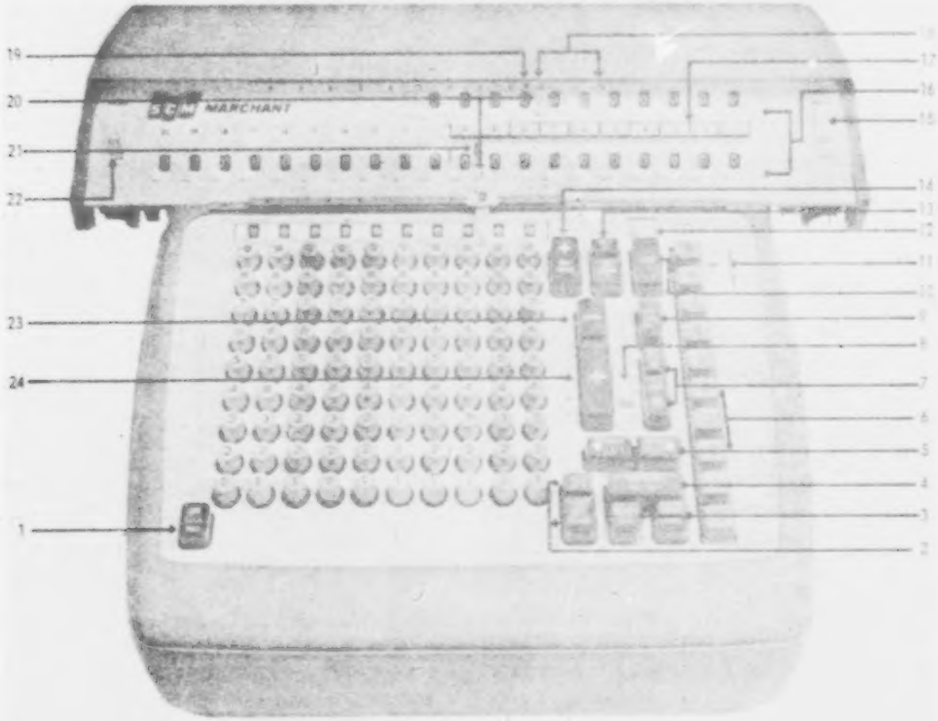
The Marchant Figuremaster Calculator, Model CMF, shown in figure 10-1 is a dial calculator. Notice the arrangement of keys and function controls shown in the figure. This calculator is a complex machine, and the material here will not cover all of its mechanisms, but will describe most of the systems for transferring numerical data and performing the basic calculations. This and other calculators have associated manufacturer's manuals which would be available for your use if you are maintaining or repairing the machines. If you are maintaining calculators, it is a good practice to limit your disassembly, adjustments, and repairs to the extent necessary to return the calculator to good working order.

COVER PLATES

The cover plates, which are shown in figure 10-2, are of the interlocking type. They protect the operator and the machine as well as give the machine a better appearance. The cover plates must be removed in a fixed sequence, starting with the carriage cover and ending with the keyboard dial cover.

Removing Cover Plates

Carriage Cover Plate: Shift the carriage to the extreme right position and remove the cord from the machine. Reach under the left and right rear corners of the carriage and you will find two toggle assemblies. Pull the toggles toward the front of the machine, raise the back of the



1. UNLOCK KEYBOARD KEY
2. KEYBOARD LOCK and CLEAR KEYS
3. DIAL CLEARANCE KEYS
4. CARRIAGE RETURN KEY
5. CARRIAGE SHIFT KEYS
6. AUTOMATIC MULTIPLIER KEYS
7. NEGATIVE MULTIPLICATION and REPEAT KEYS
8. DIVISION CLEAR RETURN KEY
   Normal position is toward operator
9. CARRIAGE NON SHIFT KEY
   Holds carriage stationary when Multiplier Key is touched
10. STOP KEY
    Stops division. Also releases NON SHIFT and REPEAT NEG X KEYS
11. UPPER DIAL CONTROL
    Normal position is on plus (+)
12. MULTIPLIER DIRECTION CONTROL
    Normal position shows arrow ➡
13. AUTOMATIC DIVISION and NEGATIVE DIVISION KEYS
14. DIVIDEND + KEY
    Clears carriage dials, enters dividend in Middle Dial, clears Keyboard Dial, enters item count in Upper Dial
15. RIGHT MIDDLE DIAL LOCK
    Normal position up. Move down to lock Middle Dials 1 through 9.
16. BLACK SLIDE SET DECIMAL MARKERS
    One for each dial, set by sliding to right
17. TABULATOR KEYS
    Any one or more keys may be set at the same time. To release all Tab Keys, touch Tab Key "10"
18. AUTOMATIC DIVISION and PERCENT DECIMALS
19. ACTIVE DIAL INDICATOR
    Orange triangle indicates carriage position and active dial
20. ORANGE QUICK-SET DECIMALS
    Easiest for routine multiplication and division
21. AUTOMATIC HALF-CENT ROUND-OFF-
    Normal position is down.
22. LEFT MIDDLE DIAL LOCK
    Normal position up. Move down to lock Middle Dials 10 through 20.
23. SUBTRACT BAR
24. ADD BAR

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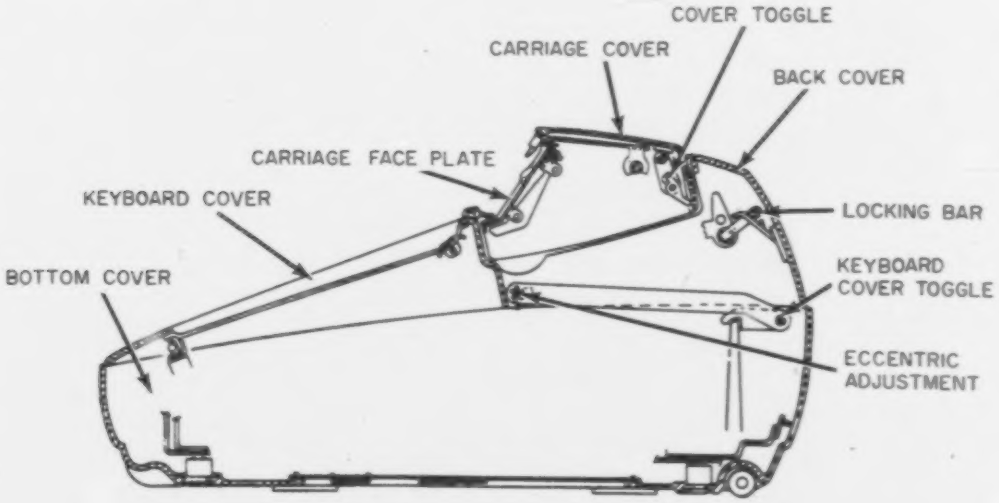
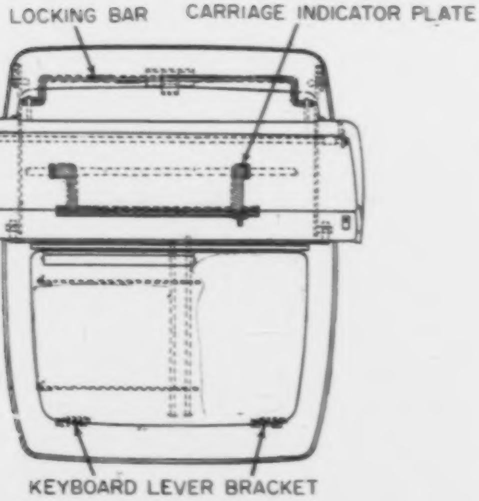
Figure 10-1.—Marchant figuremaster calculator (Model CMF).


COVER TOGGLE
CARRIAGE COVER
BACK COVER
CARRIAGE FACE PLATE
KEYBOARD COVER
LOCKING BAR
BOTTOM COVER
KEYBOARD COVER TOGGLE
ECCENTRIC ADJUSTMENT

SIDE VIEW


LOCKING BAR
CARRIAGE INDICATOR PLATE
KEYBOARD LEVER BRACKET

TOP VIEW

91.595

Figure 10-2.—Cover plates.

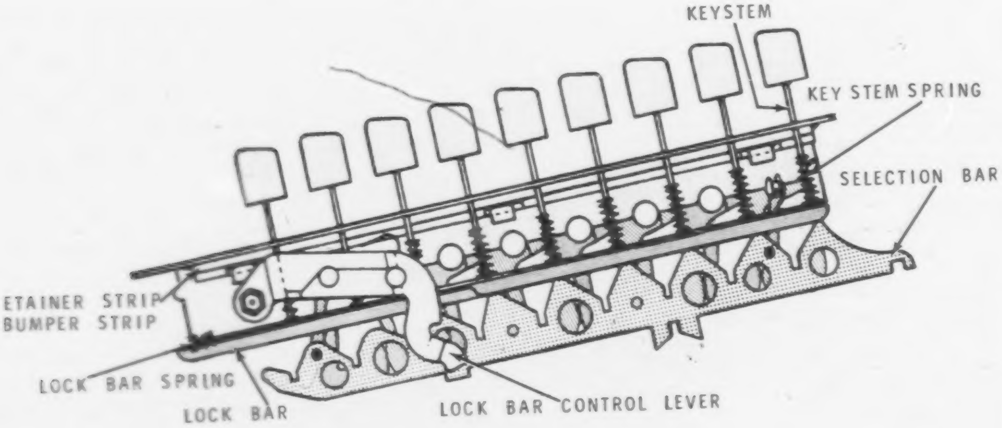


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Figure 10-3.—Numeral key section.

cover, and slide it toward the front of the machine. It can now be lifted off. Do not use force on any of the covers. If you have released them correctly they will come off easily.

Back Cover Plate: Plug the cord back into the machine, and using power, shift the carriage to the extreme left position. After removing the cord, reach under the back cover plate and pull the locking bar, shown in figure 10-2B, upward until it disengages from the cover plate. The cover can then be lifted off.

Bottom Cover Plate: Again plug in the cord. Shift the carriage to its center position, and remove the cord. Remove the keyboard cover toggles on the right and left sides (one of these is shown in figure 10-2A). Pull the entire machine toward the front of the bottom cover, grasp the carriage at both ends and lift the machine off the bottom cover.

Keyboard Cover Plate: Pull the keyboard cover toward the front of the machine and lift it off.

Carriage Indicator Cover Plate: Lift the right rear end of the carriage indicator cover plate up, and slide it to the right. Lift the left end of the plate off the shaft. Be careful because the indicator is made of light material and is easily malformed.

Carriage Face Plate: Loosen the 1/4-inch hex nuts on the upper left and right studs. When these are loose, the plate is lifted off.

Keyboard Dial Cover Plate: This plate is held by screws located at each end. Remove these screws and take off the plate.

Installing the Plates

Install plates in the reverse of the removal sequence. Be sure the plates are in position, are snug, and do not bind any of the moving parts of the machine.

NUMERAL KEYS

The numeral keys are used to enter numbers into the machine. They are arranged on a keyboard which has a monetary, or dollars and cents, format in which the key tops are colored to help the operator distinguish between cents, dollars, and thousands. The columns of keys are interchangeable, so the color coding of the board can be rearranged. If, for instance, the machine is to be used for engineering or statistical computations, the third and sixth (from the right) key sections can be exchanged. Each column is an assembly, and can be removed separately.

Figure 10-3 shows a numeral key section, and figure 10-4 gives a more detailed view of how the keys function to enter a number into the machine. When a key is depressed, a camming surface on the rear of the keystem moves the locking bar to the rear of the machine releasing any other key in the column which is depressed. When the key has traveled to the fully depressed position, the lock bar spring returns the lock bar to a position where it holds down the key by catching the camming lug of the keystem.

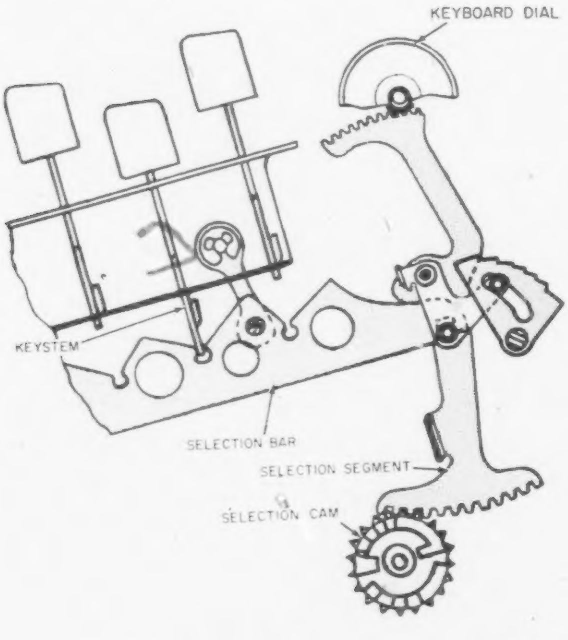

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Figure 10-4.—Selection assembly.

Depressed keys are released when the lockbar moves to the rear. On a restore cycle, release is achieved by the lockbar control lever which cams the lockbars to the rear. The keys then rise through the efforts of the keystem springs. The operator can raise the keys by pressing the keyboard clear key which operates the lockbar control levers through a bail.

Automatic restoring of the numeral keys is prevented by depressing the keyboard lock key. When this key is depressed, it immobilizes the lockbar control lever by connecting with a notch on the lever. To free the lockbar control lever the unlock key must be depressed. As keys are restored the bumper strip limits their upward motion and absorbs the shock of stopping them. If this strip is broken, a key may pop out of the board.

The number key depressed will dictate the distance the selection bar will travel. In turn, the distance the selection bar moves determines how much the selection segment, seen in figure 10-4, will rotate. The slots in the selection bar are spaced so that each higher numbered key moves the bar about 1/32 of an inch farther than the preceding key would. The figure shows the 8-key depressed, and you can see that the selection segment has rotated counterclockwise, driving the keyboard, or lower, dial indicator to indicate 8, and has also applied this rotation to the selection cam through the lower sector gear. The selection cam has a pawl mechanism which gives it a definite position corresponding to the number selected. If this pawl does not properly engage the selection cam, the cam may oscillate slightly. This effect, called flickering, will appear as a vibration of the keyboard dial. There are two forms of flicker: a sharp fast flicker caused by an adjustment problem and a slow, rolling movement caused by worn parts. You can correct slow flicker only by replacing the worn parts.

To correct flicker resulting from maladjustment, you must first determine where the adjustment must be corrected. If the flicker occurs only at one or more of the zero positions, the affected zeros are aligned by bending the ear on the associated keyboard stop dial comb. This ear engages a lug on the corresponding keyboard dial when all number keys for the dial have been released. If the flicker occurs when only one number is registered, the alignment of that number can be corrected by bending the individual keystem. If flicker occurs when any number in a key assembly is depressed, you can align the assembly after loosening binding screws located at each end of the key section. To check flicker depress the suspected number key or keys and hold down the #1 multiply key; flicker will be most pronounced under this condition.

MOTOR UNIT

The motor unit consists of a motor, governor, starting switch, and starting circuit resistor and capacitor. (See fig. 10-5).

The motor supplies the power to operate the machine. It is of the universal type, operated by either direct or alternating current of the voltage specified on the nameplate attached to the motor housing. The motor is mounted on the lower main frame in the rear center portion of the machine. It operates intermittently, rotating only when one of the control keys is depressed. Normally the only maintenance required for the motor is inspection and cleaning. Occasionally brushes must be replaced. Motor brushes should be free in their holders. The face of the brush should be smooth and shiny. A dull or pitted surface indicates a sticking brush or insufficient spring pressure on the brush.

The speed of the motor is controlled by the governor. The governor is of the centrifugal

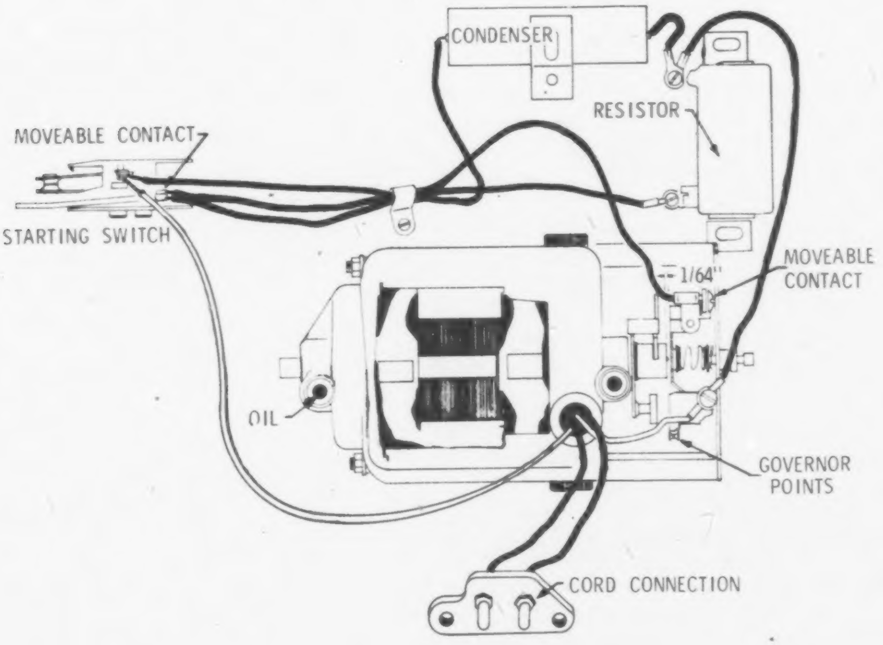

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Figure 10-5.—Motor unit.

type, locked to the end of the motor shaft with a setscrew, and rotating with the motor shaft. As the speed of the motor increases to a specified rate the governor acts to push a ball out from the end of the shaft which causes the governor points to open. The points are mounted on the end plate of the motor and do not rotate. An adjustable spring holds the points together, and permits the motor speed at which the points open to be adjusted. The movable contact permits the gap between the governor ball and point actuating arm to be set at the specified 1/64-inch distance, with the motor stopped. When the motor is stopped or not up-to-speed the points are closed, permitting the full current to go to the motor. When the points open, the motor receives reduced current through the resistor.

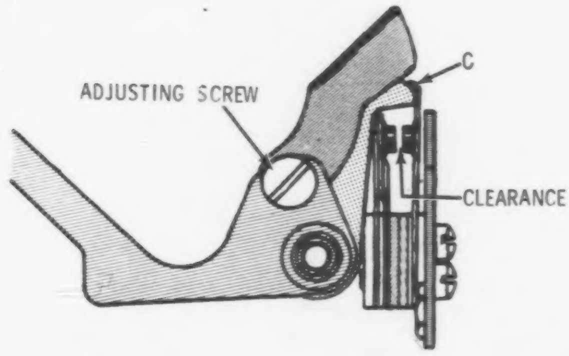
The starting switch, shown in figure 10-6, consists of a set of points mounted between fiber spacers. In the open position the gap between these points should be from .020 inch to .030 inch. You adjust the gap by loosening the adjusting screw and positioning the fiber arm (point C in figure 10-8) which holds the points open.

Removal and Installation of Motor Unit

To get the motor unit (fig. 10-7) out of the machine, it is necessary to first remove a cross brace which spans the bottom of the machine, the motor drive bearing plate, and several screws which connect the motor support frame to other components of the machine. The procedure is started with the machine upside down on the bench, with the rear of the machine towards you. Figure 10-7A shows the cross brace which you remove first. Take out the screws at each end of the brace (1, 2, 3, and 4) and disconnect the springs from points 5 and 6. Lift off the brace.

One end of a spring is attached at point 6 of the motor support frame shown in figure 10-7B the other end of this spring must be detached from the setting line shaft. The spring remains attached to the frame.

Remove the two screws holding the motor drive bearing plate (shown in figure 10-7D) to the side support frame. When the plate is free, it is slid off the shaft to the right.



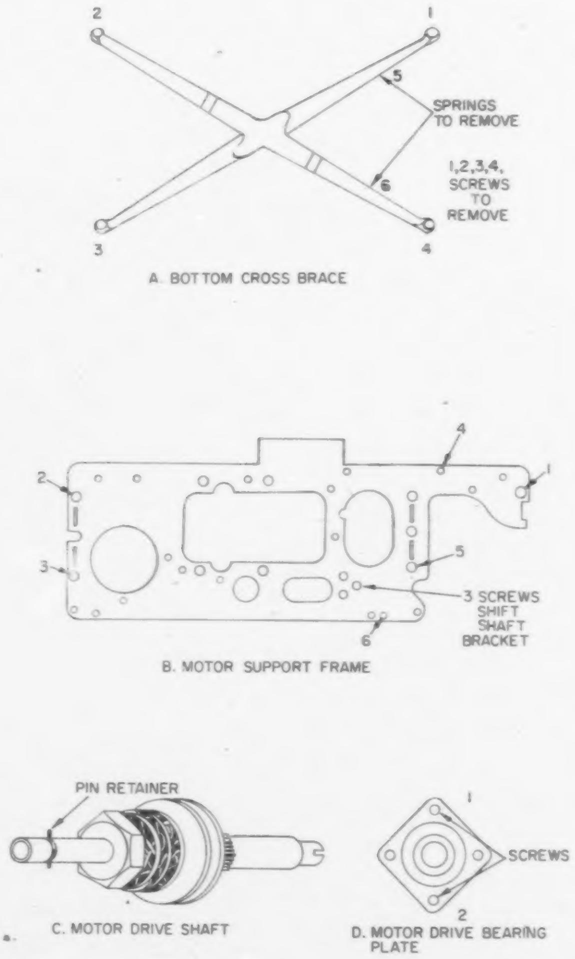
91.607
Figure 10-6.—Starting switch.

A bracket for the shift shaft is attached to the motor support frame by three screws which now are removed.

The motor support frame can now be released from the side support frame after you release the screws located at positions 1 through 5 in figure 10-7B. In taking out these screws be careful not to lose the square nuts on the other side of the motor support frame.

To remove the motor unit and motor support frame, take the motor shaft pin retainer from the motor drive shaft (fig. 10-7C). Remove the drive shaft pin, and the drive shaft can be disengaged as you work the motor unit out of the machine toward the left side.

To replace the motor unit, reverse the above steps.



A. BOTTOM CROSS BRACE

B. MOTOR SUPPORT FRAME

C. MOTOR DRIVE SHAFT

D. MOTOR DRIVE BEARING PLATE

91.606
Figure 10-7.—Motor mounting.

DRIVE ASSEMBLY

The drive assembly, figure 10-8, consists of the drive shaft and gears. The drive shaft is connected to the motor shaft with a pin and retaining wire. Note that in figure 10-8A the gear train is folded out to give a better view of the parts. The slot at the end of the drive shaft connects with a handcrank by which the machine can be manually driven through clearing and add operations.

Provision is made in the design of the gear train to adjust clutch tension, drive shaft bearing alignment, and the mesh of the compound drive idler gear. The need to correct the tension of the clutch is indicated either by a tendency of the motor to stall when there is a lockup in the gear train, or for the clutch to slip during normal operation. You make the adjustment by unlocking the two nuts on the drive shaft and either increasing or decreasing the spring tension by turning the adjusting nut toward or away from the clutch assembly. When the tension is satisfactory, tighten the jam nut. If adjusted correctly, the clutch will produce a rasping sound when there is an overload on the machine. This sound should warn the operator to stop the machine.

The bearing on the opposite end of the drive shaft from the motor is a self-aligning bearing.

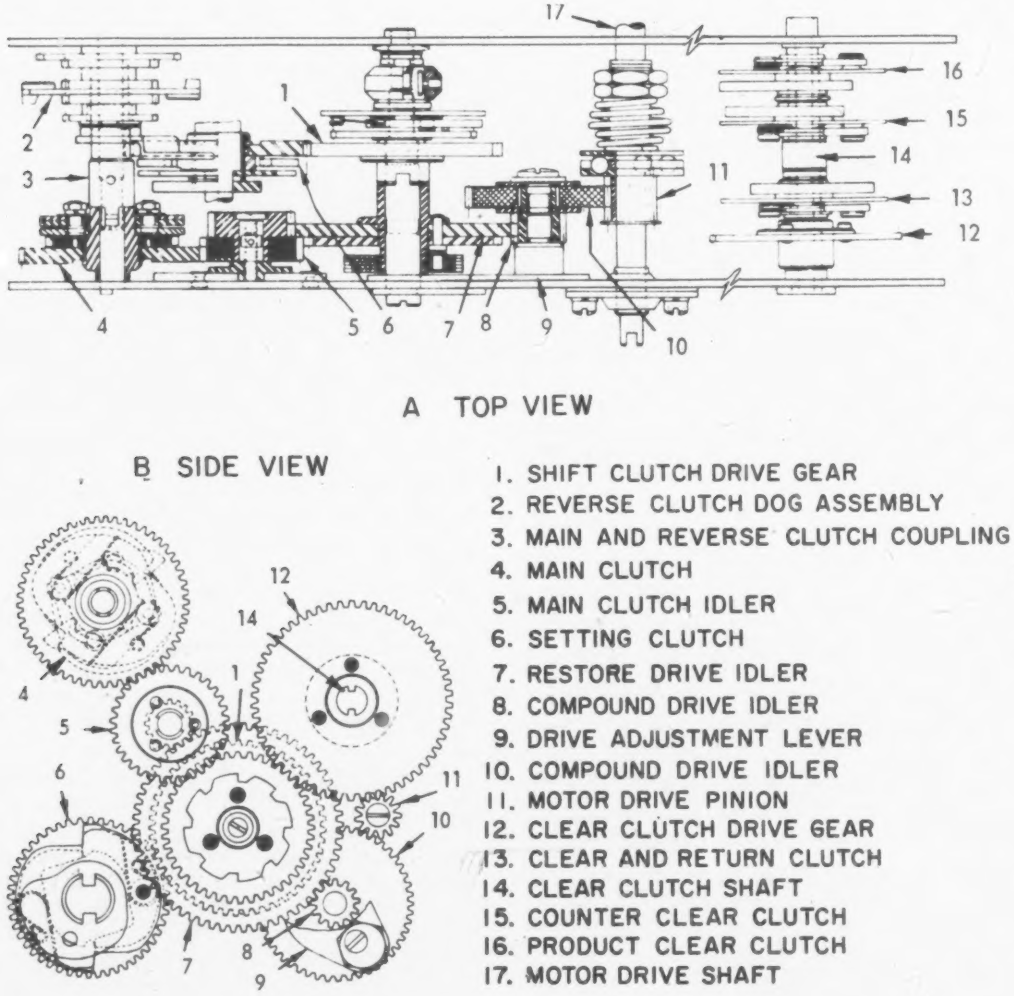

17
16
15
14
13
12
11
1
2
3
4
5
6
7
8
9
10
A TOP VIEW
B SIDE VIEW
12
14
1
4
5
6
11
10
8
7
9
1. SHIFT CLUTCH DRIVE GEAR
2. REVERSE CLUTCH DOG ASSEMBLY
3. MAIN AND REVERSE CLUTCH COUPLING
4. MAIN CLUTCH
5. MAIN CLUTCH IDLER
6. SETTING CLUTCH
7. RESTORE DRIVE IDLER
8. COMPOUND DRIVE IDLER
9. DRIVE ADJUSTMENT LEVER
10. COMPOUND DRIVE IDLER
11. MOTOR DRIVE PINION
12. CLEAR CLUTCH DRIVE GEAR
13. CLEAR AND RETURN CLUTCH
14. CLEAR CLUTCH SHAFT
15. COUNTER CLEAR CLUTCH
16. PRODUCT CLEAR CLUTCH
17. MOTOR DRIVE SHAFT

Figure 10-8.—Drive unit. 91.608

If you doubt that the shaft is aligned, loosen the two screws holding the bearing assembly to the frame, and start the motor. While the motor is running tighten the screws by slightly turning first one and then the other until they are tight. The bearing will now be centered.

The pinion gear on the drive shaft meshes with a fiber idler gear, called the compound drive idler gear (10 in figures 10-8A and B). The compound idler gear shaft is mounted on an adjusting lever or plate, which has some freedom of movement. The adjusting lever position is regulated by an eccentric nut, which can be seen in the lower right of figure 10-8B. If the gears are noisy or show other evidence of improper mesh, loosen the lock screw on the eccentric nut, and with the motor running, turn the nut until the quietest operating position is obtained, and then tighten the lock screw.

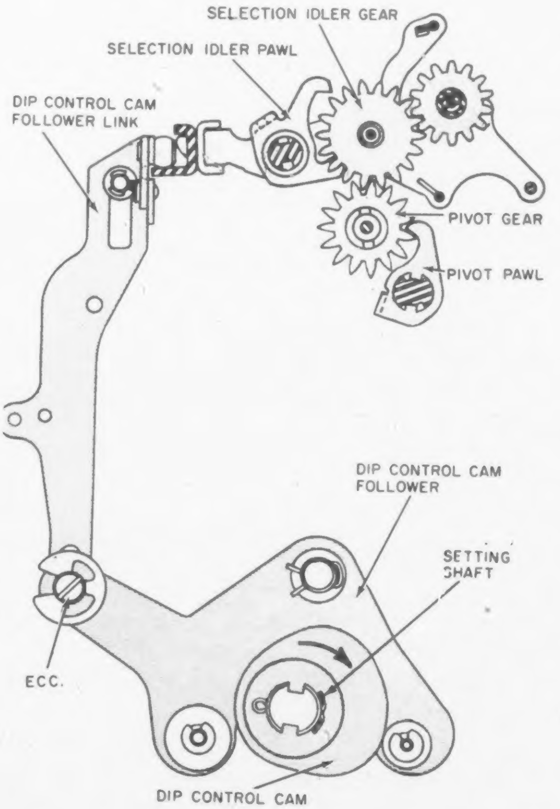
CARRIAGE

The carriage consists of two separate sections: the product, or lower, carriage and the counter, or upper, carriage. Gears in the lower carriage engage with gears in the actuator unit during the machine calculating operations. The calculating operations accumulate the product of multiplication, the sum of addition, or the difference of subtraction, and display this information on the carriage dials (called the middle dials). The upper carriage registers the number of machine cycles on the upper dials. In multiplication the upper carriage displays the multiplier, and in division it displays the quotient.

Carriage Operation

The machine uses three operations or "cycles" to transmit data from the keyboard to the carriage. These are called the setting cycle, the main cycle, and the restore cycle.

In the setting cycle the carriage is pulled down to its dip position, where the selection idler gear of the carriage meshes with the pivot gears of the actuator. This position is shown in figure 10-9.



91.596

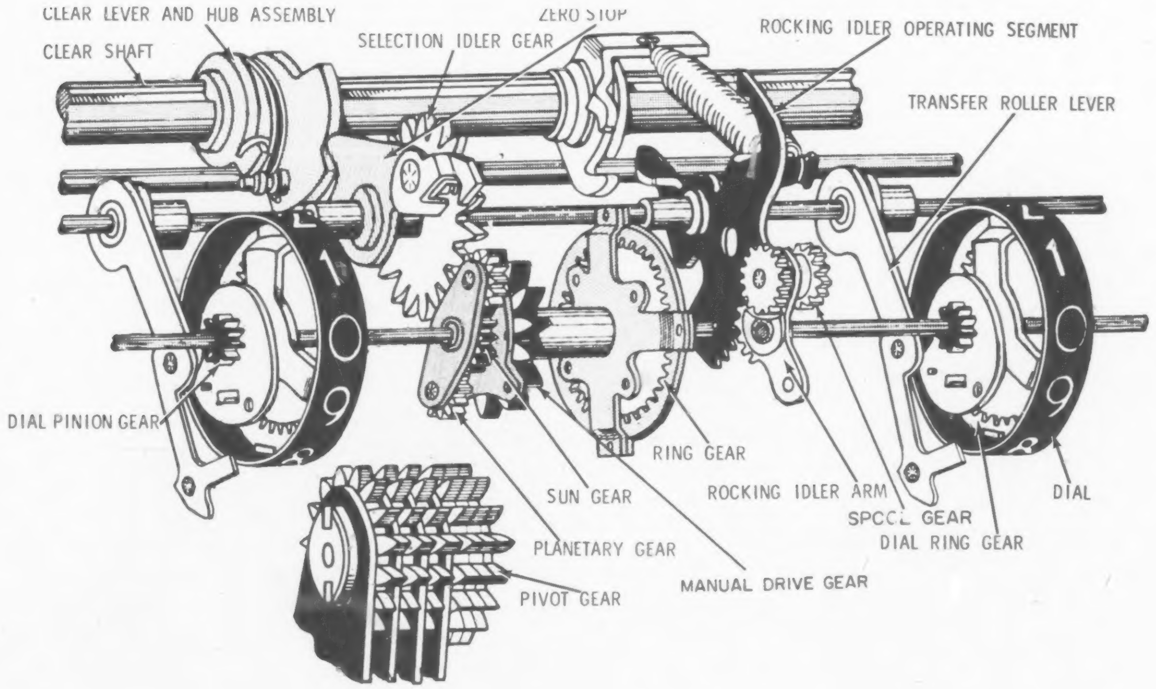
Figure 10-9.—Carriage positioning.

In the main cycle the number that has been set up on the keyboard is entered into the carriage through the cam, links, and levers that were positioned during the setting cycle.

In the restore cycle the carriage is raised, and the components of the actuator are restored to their ready positions so the next entry can be made.

Figure 10-9 shows the mechanism used to dip the carriage. Two of these mechanisms, one located on each end of the machine, must be adjusted so that the carriage is pulled down evenly. If they are not even the machine will produce a growling sound when the carriage is dipped. As the dip control cams turn, they rock the dip control follower cams on their pivots. The followers are connected to links which pull down the carriage and hold it down during the setting and main cycles. Eccentric adjusting screws between the cam followers and links permit the distance the carriage is pulled down to be adjusted.

When the carriage has been dipped the selector idler pawls are disengaged and the selector idler gears are free to be turned by the pivot gears. Figure 10-10 shows the middle dial (lower dials of the carriage) mechanism, out of engagement with the pivot gear. The pivot gear turns the selection idler gear which is in mesh with the main drive gear on the dial shaft. As the main drive gear turns it carries the planetary gears around the sun gear. When the sun gear does not turn, the planetary gears will carry the dial around by meshing with the ring gear inside the dial. You will notice that each dial has a pinion gear to the left side of its hub. This pinion meshes with the spool gear on the rocking idler arm. The rocking idler assembly stores the movement of the dial pinion until it has completed one revolution. When the carriage is in the dip, as the pinion on a dial turns it turns the spool gear, which turns the ring gear attached to the planetary gear assembly. This ring gear is connected to the sun gear, and the gear train from one dial to the next has a ratio of 10 to 1. While the carriage is dipped a partial carry will appear in the left dial, but as the carriage rises the transfer roller lever riding on the dial cam of the right dial turns the rocking idler operating segment to remove the partial carry. This will occur until the right dial has turned to its "0" position, when the roller will ride up on the highest part of the dial cam, and allow the carry to remain in the left dial.


CLEAR LEVER AND HUB ASSEMBLY
CLEAR SHAFT
ZERO STOP
SELECTION IDLER GEAR
ROCKING IDLER OPERATING SEGMENT
TRANSFER ROLLER LEVER
DIAL PINION GEAR
RING GEAR
SUN GEAR
ROCKING IDLER ARM
SPOOL GEAR
DIAL
DIAL RING GEAR
PLANETARY GEAR
MANUAL DRIVE GEAR
PIVOT GEAR

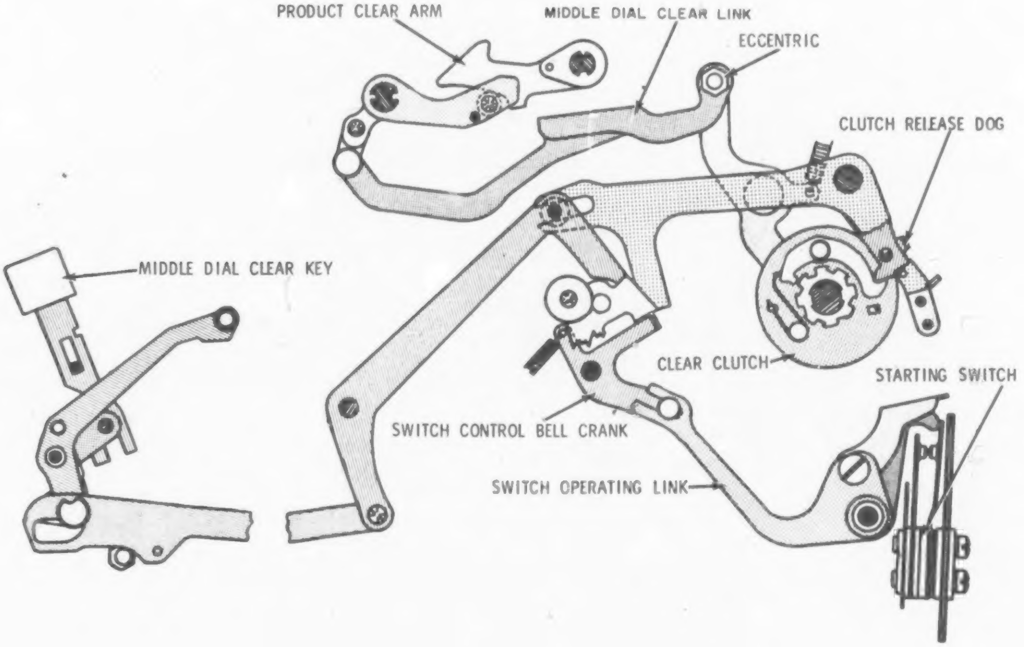
91.597

Figure 10-10.—Dial assembly.

MIDDLE DIAL CLEARING.—The purpose of the middle dial clear key is to activate the mechanism that restores all the dials to their zero positions. When the clear key is depressed, its linkage releases the clutch dog from the clear clutch and starts the motor, as illustrated in figure 10-11. The clear clutch drives the middle dial clear linkage which rocks the product clear arm. The clear arm is keyed to the clear shaft, so the effect of the clear clutch is to partially rotate the clear shaft. Mounted on the clear shaft are clear lever and hub assemblies for each dial. A detail of one of these assemblies is shown in figure 10-12. The purpose of the spring-loaded hub between the shaft and lever is to absorb shock and prevent strain and breakage in case of a lock up.

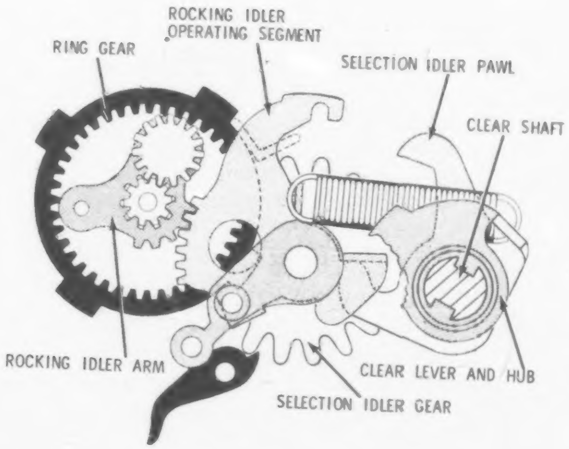
The clear levers use a cam action to disengage the selector idler pawls from the selection idler gears, leaving these gears free to turn. As the idler pawl rises it also contacts the rocking idler operating segment and rotates the segment. The segment turns the ring gear and dial. The mechanism shown in figure 10-13 catches and holds the zero stop lug on the dial when it reaches the zero position. When the clear lever restores to its normal position, spring tension disengages the zero stop mechanism from the zero stop lug. Failure of a dial to stop smartly at zero during the clear operation indicates a malfunction, such as a broken or sticking part of a displaced spring in the zero stop mechanism.

UPPER DIAL MOTIVATION.—The upper dials record the number of cycles used by the machine to perform a calculation. If the machine were dividing three into nine, the upper dial would count the number of times that three is subtracted from nine to bring the middle dial to zero. These dials are operated by an assembly composed of one counter finger and seven transfer fingers. As the carriage shifts, the dial in line with the #1 key section will be operated by the counter finger. The fingers turn the dials in either a


PRODUCT CLEAR ARM
MIDDLE DIAL CLEAR LINK
ECCENTRIC
CLUTCH RELEASE DOG
MIDDLE DIAL CLEAR KEY
CLEAR CLUTCH
STARTING SWITCH
SWITCH CONTROL BELL CRANK
SWITCH OPERATING LINK

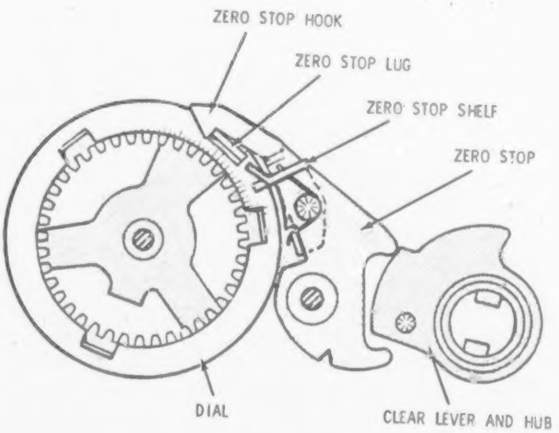
91.598

Figure 10-11.—Middle dial clear mechanism.


ROCKING IDLER OPERATING SEGMENT
RING GEAR
SELECTION IDLER PAWL
CLEAR SHAFT
ROCKING IDLER ARM
CLEAR LEVER AND HUB
SELECTION IDLER GEAR

91.599

Figure 10-12.—Dial clearing.


ZERO STOP HOOK
ZERO STOP LUG
ZERO STOP SHELF
ZERO STOP
DIAL
CLEAR LEVER AND HUB

91.600

Figure 10-13.—Zero stop.

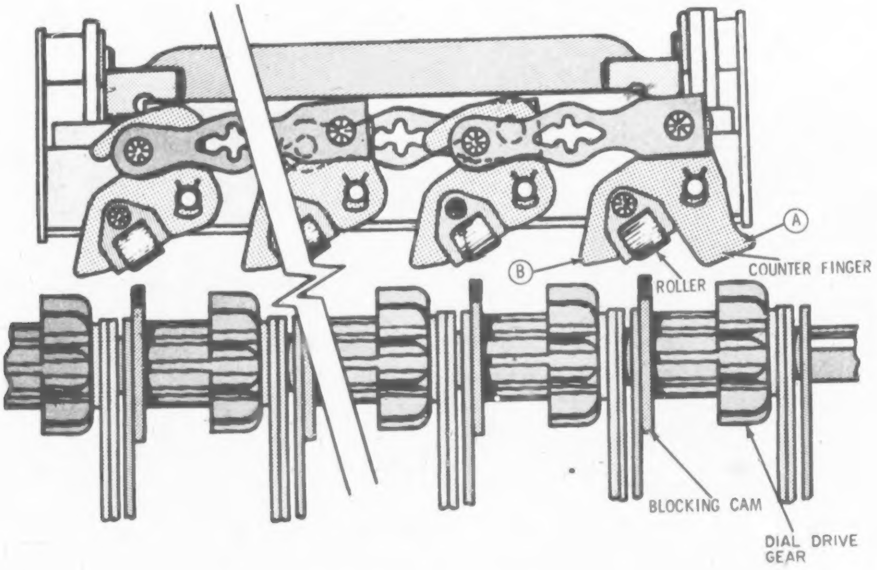
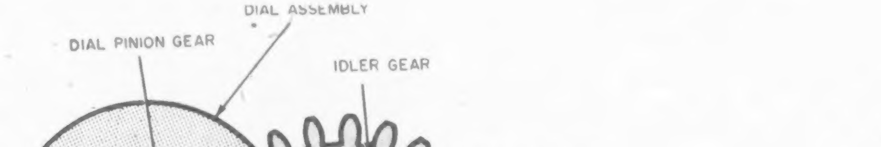

A
B
ROLLER
COUNTER FINGER
BLOCKING CAM
DIAL DRIVE GEAR

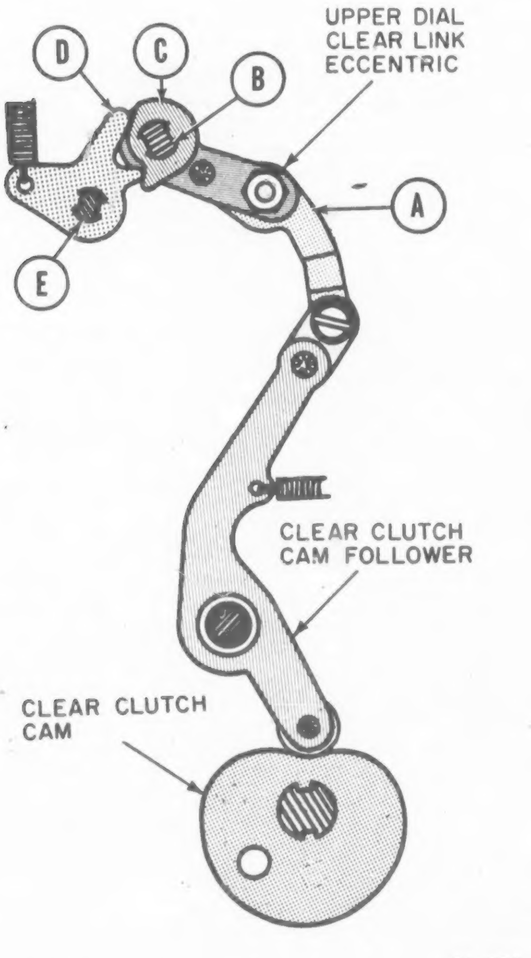
Figure 10-14.—Counter fingers and gears. 91.601

positive or negative direction depending on the function selected on the machine. The operating fingers and the gears that move the dials are shown in figures 10-14 and 10-15. In the top view, figure 10-14, you can see tip A of the counter finger which will enter the dial gear and rotate it one tooth at a time. The roller on the counter finger assembly will strike the blocking cam and prevent tip B from engaging the gear for the next digit. Figure 10-15 is a side view, and here you can see that the tenth time the dial gear has been moved the opening in the blocking


DIAL ASSEMBLY
DIAL PINION GEAR
IDLER GEAR
DIAL DRIVE GEAR
BLOCKING CAM
COUNTER FINGER ASSEMBLY

91.602

Figure 10-15.—Upper dial gear train.



91.603
Figure 10-16.—Upper dial clear link.

cam will permit the other side of the finger to advance the adjacent dial.

UPPER DIAL CLEARING.—The upper dial clear key serves to engage the clear clutch which rotates the clear clutch cam. The cam operates the linkage shown in figure 10-16, which turns the clear shaft (E). The clear shaft carries a clearing mechanism for each dial. One of these counter dial clearing mechanisms is shown in figure 10-17. When the clear shaft (E) turns, the clear lever arm (A) is forced down against the dial clear cam (B). The pressure of the lever arm roller against the cam causes the dial to rotate until the roller drops into the notch, holding the dial at the zero position. The position of the cam determines direction of rotation. At the end of the clear cycle, the lever and the rest of the mechanism return to their normal positions, leaving all upper dials reading zero.

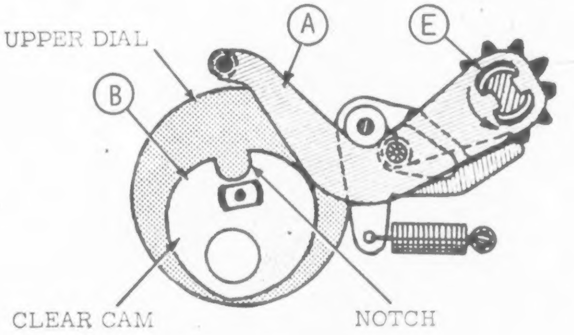


Figure 10-17.—Counter dial clearing. 91.604

Removal of the Carriage

Repairing malfunctions and making adjustments in the upper and middle dial units may require removal of the carriage to gain access to the mechanism. The first step in removing the carriage is to take the wire clip off the left end of the upper carriage rod. This permits you to remove the carriage rod spacer and pull the carriage rod out. You draw the rod out to the right, taking care to catch the long sleeve as it is released by the rod, to prevent its falling into the machine. Move the cam and spacer to the right side of the rod, and leave them on the rod. On the left end of the lower support rod, remove the wire keeper, and slip off one long spacer and one short spacer. Take off the lower support rod lever and the small spacer located behind it. Now take the lower screw out of the carriage support bracket on the right side of the carriage, and swing the bracket up out of the way. Disengage the product clear arm from the support rod lever, and pull the lower carriage rod out of the carriage to the right. Take care not to lose the spring on the center of this rod. With the rod clear, the carriage can be removed by lifting its rear part up and toward the front of the machine.

Carriage Disassembly

The carriage can be split to gain access to the middle dials. After placing the carriage on a bench, remove the two screws from the right-hand side of the front shaft retainer and take off the retainer. Loosen the two screws that hold the rear shaft retainer on the right side, slide up the retainer until the holes for the shaft are exposed, and pull the center shaft out to the right. A lock shaft and comb are located between the upper and middle dials, with the shaft directly over the comb. Remove both of these components. Unhook the carriage lift springs from the studs at each end of the carriage and open the carriage like a book.

Carriage Adjustments

The right and left carriage dip mechanisms are adjusted to obtain the correct mesh between the selection idler gears and the pivot gears. The relation of these parts is shown in figure 10-9. The depth of mesh between these gears must be kept even across the carriage. If the mesh is too deep, they will make a growling noise. If only the tips of the gears are meshed the dials may not function properly. The adjustment is made on the eccentrics between the carriage positioning links and the carriage positioning levers. These are adjusted so the carriage is dipped evenly and locks just above the point where the gears can be heard to growl.

Middle Dial Timing

Timing, or alignment, of an assembly for one of the middle dials may occasionally be necessary. This timing is done with the assembly removed from the machine and mounted on a shaft so a timing wire can be inserted through holes in the dial cams, drive gear assembly, ring gears, and rocking idler arms. These components are shown in figure 10-10, and if you look carefully you can see the timing holes. Notice that the ring gear has four holes; when any of these four are lined up with the timing holes in the other three components, the assembly is aligned.

To remove an assembly the carriage must be opened and the dial assembly shaft must be drawn out until the faulty dial assembly is released. To avoid releasing other dial assemblies during this operation, insert the lock shaft from the carriage, which has the right diameter, through one end of the dial assemblies and withdraw the dial shaft from the other end. When the faulty dial is located where the two shafts butt, they are separated enough to release the assembly.

When the assembly to be timed is out of the carriage, it is mounted on a shaft so the components turn in proper relation to each other. A wire or thin shaft, such as the long thin shaft that locks the comb, is needed to go through the timing holes in the components. The timing holes are aligned as the wire is thrust through them. The aligned assembly is then gripped with a special pair of pliers (Marchant dial pliers) and the timing wire can be withdrawn. Now you can slide the assembly off the shaft you used as a mounting, and can replace the assembly in the carriage. To replace it, pull the rocker idler operating segment forward, and as the assembly is placed in position, be sure the top tooth of the operating segment is over the top tooth of the rocking idler in the dial assembly. Push the dial shaft back into position, and inspect the dial assemblies to see that they are in time. All the zeros should line up, and the lugs on the ring gears should also be in line. If an assembly is not in time, remove it and align it again.

Middle Dial Clear Mechanism Adjustment

The principal adjustment is of the amount of throw of the middle dial clear link, shown in figure 10-11. If this throw is too short, the dials will not return to zero. If the throw is too long, the dials will return to zero before the end of the clear cycle, causing unnecessary strain on the zero stops and lugs.

The throw of the clear link is adjusted at the eccentric, which you can see at the upper right part of figure 10-11. This eccentric is adjusted, when the handcrank is operated, until all the dials clear smartly to the zero position, neither stopping short nor running over.

When all the middle dials are set at 1, they should clear to zero at the same time. If this is not the case, make the individual dial clearing adjustment by forming the tail of the selection idler pawl. If a dial clears before the rest, form the tail out (away from the carriage). If it clears after the rest, form the tail in.

Adjustment of the Upper Dial Clearing Mechanism

The overall adjustment of the upper dials is made by changing the position of the upper dial clear link eccentric (fig. 10-16). When the upper dials are cleared with the handcrank, the rollers should enter the notch in the clear cams of the

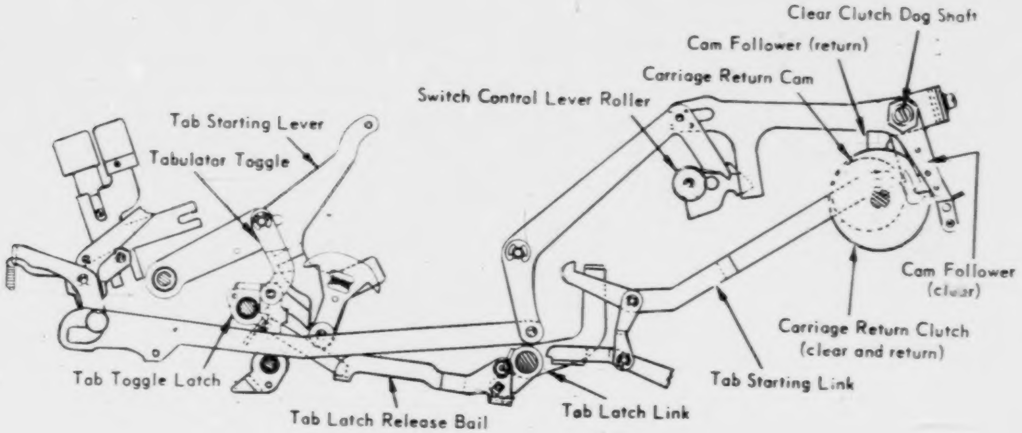


Figure 10-18.—Selective carriage return. 91.617

dials, but should not bottom. There is no individual adjustment of the clearing mechanisms for the upper dials.

Reassembly of the Carriage

Close the carriage. Replace the product clear arms, making sure their points are up. Put the carriage lift springs back on the studs. Move the rear shaft retainer so the access holes are open, and insert the center shaft. Slide the shaft retainer down so it blocks the holes, and tighten the screws. Insert the lock shaft and comb, making sure the large notch on the comb goes to the left and to the rear. Be sure the lock shaft is on top of the comb and not in front of it; if the comb is in the proper position, the shaft will slip in easily. The shaft should never be forced. Now replace the front shaft retainer on the right end of the carriage and the carriage is ready to put back on the machine. To replace the carriage reverse the procedures used to remove it.

SELECTIVE CARRIAGE RETURN

Depression of the carriage return key opens the carriage return clutch. The linkage between the carriage return key and the carriage return clutch is almost identical with the linkage of the middle dial clear key.

The cam follower (clear) and the cam follower (return), figure 10-18, are assembled together on the clear clutch dog shaft. They transmit motion from the carriage return cam to the tab starting link, which extends forward in a position to engage the tab latch link.

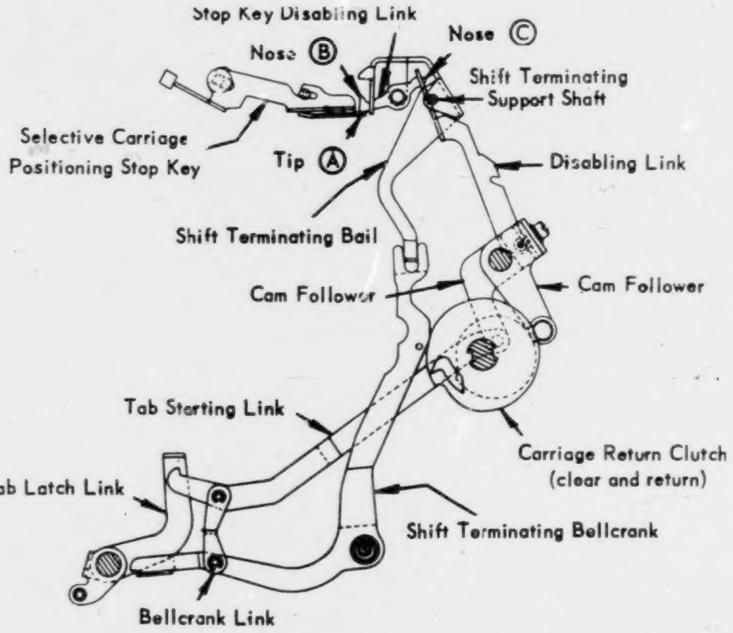
Carriage Shift Initiation

Depression of the carriage return key causes the carriage return clutch to engage. As the clutch revolves, it cams the tab starting link to the rear, which rocks the tab latch link clockwise. The link rocks the tab toggle latch counterclockwise to release the tabulator toggle. This action releases the tab starting lever and initiates a carriage shift.

Carriage Shift Disabling

When the carriage return key is depressed and the carriage is at a tab key position, it is retained in this position by an immediate shift termination. This immediate shift termination also prevents the carriage shifting out of position if the operator depresses the carriage return key twice.

In figure 10-19 when the carriage return clutch revolves, the cam followers rock counterclockwise and lift the disabling link. The upward movement of the link lifts nose C of the stop key disabling link and lowers nose B. When the carriage is at a tab set position, nose B contacts tip A of the stop key. As the disabling link continues to rise, the shift terminating bail is rocked clockwise about its shaft. The ear on the lower end of the bail operates in a fork in the upper end of the shift terminating bellcrank, rocking it in a counterclockwise direction. The bellcrank and its link pull the forward end of the tab starting link down below the ear of the tab latch link, preventing a carriage shift out of the tab position.


Stop Key Disabling Link
Nose Ⓒ
Nose Ⓑ
Shift Terminating Support Shaft
Selective Carriage Positioning Stop Key
Tip Ⓐ
Disabling Link
Shift Terminating Bail
Cam Follower
Cam Follower
Tab Starting Link
Carriage Return Clutch (clear and return)
Tab Latch Link
Shift Terminating Bellcrank
Bellcrank Link

91.618

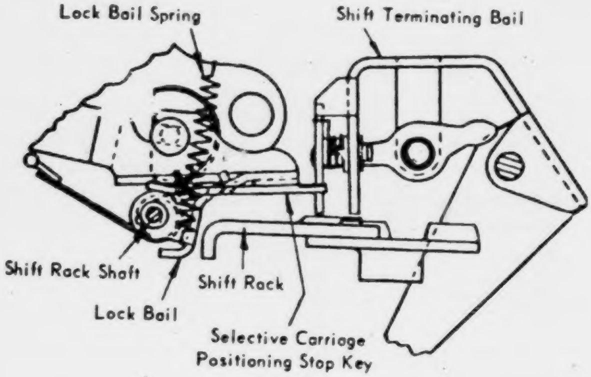
Figure 10-19.—Carriage shift disabling.

Carriage Shift Termination

If the carriage return clutch, figure 10-19, operates when the positioning stop key at a particular point is retracted, nose B of the stop key disabling link rocks down because it is no longer blocked; consequently, no clockwise motion can be imparted to the shift terminating bail. Since the carriage shift is not terminated, the carriage shifts to the depressed positioning stop key. In figure 10-20, the positioning stop key is shown depressed and latched by the lock bail. The bail is rotated counterclockwise about the shift rack shaft and held against the key by the tension of the lock bail spring.

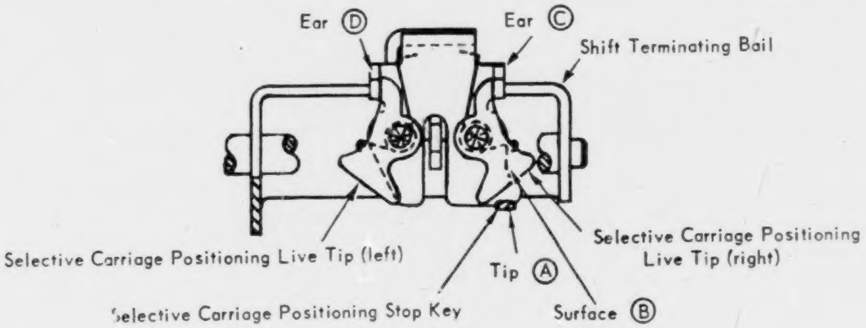
As the carriage nears a latched positioning stop key, figure 10-21, the tip A on the key contacts camming surface B on the positioning live tip, right. Because the rotation of the live tips is prevented by ears C and D, the shift terminating bail, figure 10-21B, is rocked clockwise.

If the shift is again started after having been stopped as previously described, the position stop key contacts surface E of the live tip, (left), figure 10-21B. This action rocks the live tip against its spring, causing it to yield and permit the position stop key to pass under the live tip. The shift continues until another latched stop key, or the end position is reached.

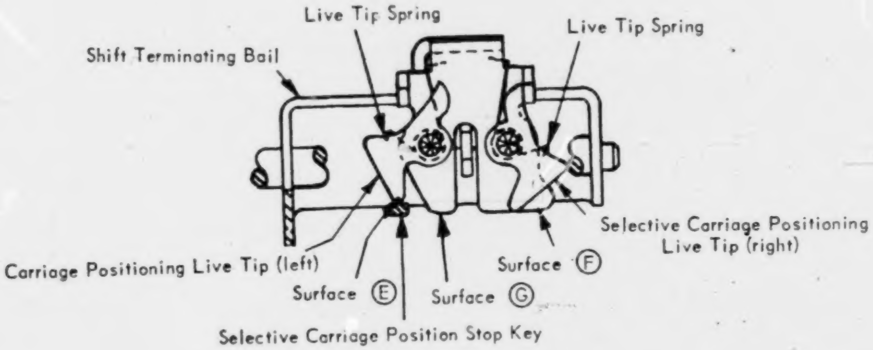

Lock Bail Spring
Shift Terminating Bail
Shift Rack Shaft
Shift Rack
Lock Bail
Selective Carriage Positioning Stop Key

91.619

Figure 10-20.—Carriage shift termination.


Ear Ⓓ
Ear Ⓒ
Shift Terminating Bail
Selective Carriage Positioning Live Tip (right)
Selective Carriage Positioning Live Tip (left)
Tip Ⓐ
Selective Carriage Positioning Stop Key
Surface Ⓑ

A. Latched key position.


Live Tip Spring
Live Tip Spring
Shift Terminating Bail
Selective Carriage Positioning Live Tip (right)
Carriage Positioning Live Tip (left)
Surface Ⓕ
Surface Ⓔ
Surface Ⓖ
Selective Carriage Position Stop Key

B. End position termination.

91.620

Figure 10-21.—Carriage position.

End Position Termination

In the end position, the carriage is stopped by the ears at either end of the shift rack, figure 10-20. The ear contacts surface F or G, figure 10-21B. The contact causes the shift terminating bail, figure 10-21A, to rock clockwise and terminate the shift.

ADD BAR

The depression of the add bar rocks the add operating latch, figure 10-22, clockwise, raising ear A of the latch from the path of the add operating lever. Raising this ear allows the add operating assembly to rock clockwise, which moves the add operating bar down and to the rear of the machine. The operating bar contacts the operating bar link, disengaging the release dog from the setting clutch, allowing the clutch to operate. The operating bar link is then cammed off the release dog, allowing the dog to stop the clutch at the half-cycle position. The setting clutch dips the carriage to mesh the pivot and sector idler gears, and engages the main clutch. Operation of the main clutch adds the keyboard dial setting to the middle dials on the carriage.

Keyboard Release

Depression of the add bar lowers the rear end of the keyboard clear operating bar, figure 10-23, positioning ear B in front of the keyboard clear lever. As the setting shaft rotates, the keyboard

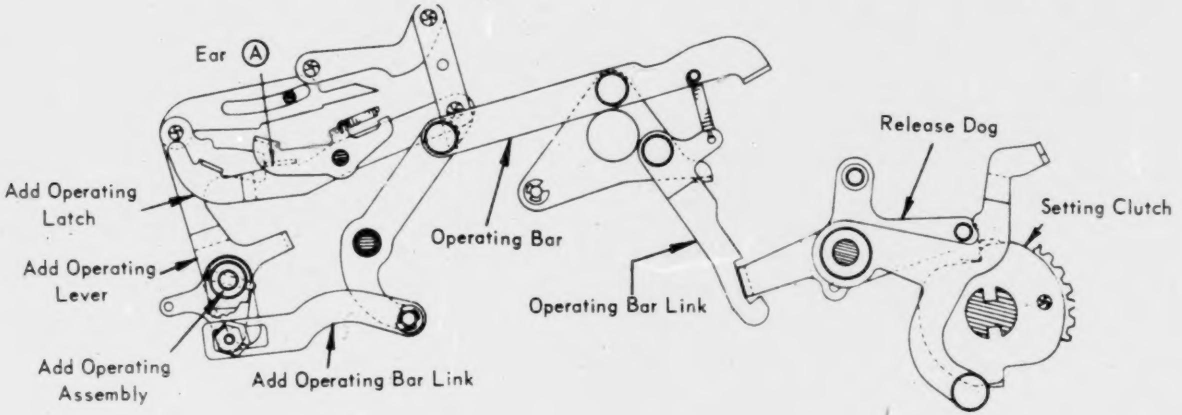


Figure 10-22.—Add bar.

clear shaft assembly is rocked counterclockwise by the main clutch starting arm and the clear link. The keyboard clear lever moves the keyboard clear operating bar forward, rocking the AUTO KB (keyboard) clear lever clockwise. Tip C contacts the eccentric stud and rocks the AUTO KB clear lever link clockwise. Rocking this link moves the lock bail link to the rear, causing the selection factor lock bail to rock clockwise. The bail contacts nose D of the lock bar control lever, rocking them counterclockwise. These levers raise the camming surface X to contact ear E and cam the lockbars to the rear. This action releases any previously latched keys (except those that are latched by the keyboard clear key).

Relatching of Operating Lever

The keyboard clear shaft assembly moves the power add restore link, figure 10-24, to the rear. This link rocks the add operating lever assembly counterclockwise and relatches it. If the add bar is held depressed, spring tension moves ear P on the add operating lever latch, figure 10-25, into the path of the add reverse lock. The latch position prevents the add operating lever assembly from returning to the rear. When the add bar is released, the add operating latch rises and engages ear M of the lever latch, rocking ear P away from the add reverse lock. This action occurs only after ear F of the add operating latch has dropped into a position to block the add operating lever assembly.

The carriage will automatically shift whenever it cycles through a dip. To prevent a shift from occurring during addition and subtraction the add operating lever disconnects the automatic shift feature. The automatic shift mechanism will be discussed later in this chapter.

SUBTRACT BAR

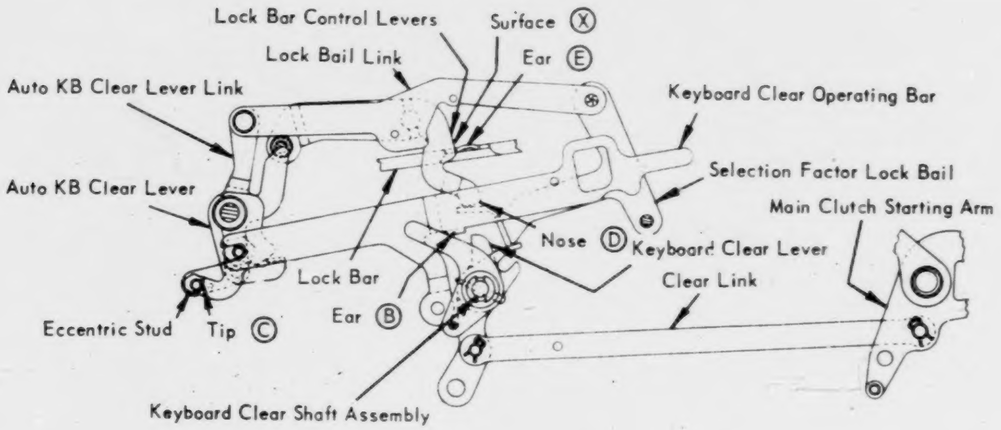
Subtraction and addition are similar operations in the Marchant Model CMF. When the subtract key is depressed, the subtract key roller, figure 10-26, rocks the reverse setting assembly clockwise, positioning it to the negative position. Releasing the subtract key before the machine starts allows the rear end of the add reverse lock to remain under ear T, holding the mechanism in its negative position until the add operating lever assembly is latched.

Add Operating Lever Restore

When the stop key is depressed, surface A, figure 10-27, rocks the stop connecting lever clockwise and rocks the stop and restore assembly counterclockwise. This action moves the add operating lever restore link to the rear and rocks the add operating lever shaft assembly counterclockwise, restoring it to its latched position. (See fig. 10-27 on page 290).

AUTOMATIC MULTIPLICATION

When any control key is pressed the motor is switched on, and when the function which has been selected is completed, the motor is automatically switched off. The numbers set in the keyboard dials are transferred to the middle


Lock Bar Control Levers
Surface Ⓧ
Lock Bail Link
Ear Ⓔ
Auto KB Clear Lever Link
Keyboard Clear Operating Bar
Selection Factor Lock Bail
Auto KB Clear Lever
Main Clutch Starting Arm
Nose Ⓓ
Keyboard Clear Lever
Lock Bar
Clear Link
Ear Ⓑ
Eccentric Stud
Tip Ⓒ
Keyboard Clear Shaft Assembly

91.612

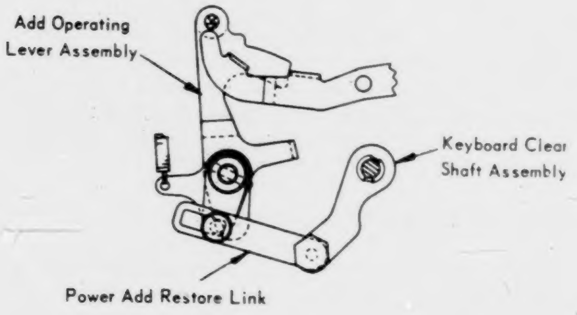
Figure 10-23. — Keyboard release.

dials by the rotation of the main clutch. During multiplication the numbers are entered repeatly to the middle dials. Multiplication is achieved by rapidly adding the numbers to the middle dial mechanism. The number of the multiplication key depressed determines the number of cycles, or times the number will be added.

Each multiplication key operates a linkage which starts the motor and positions the linkage of the selection mechanism.

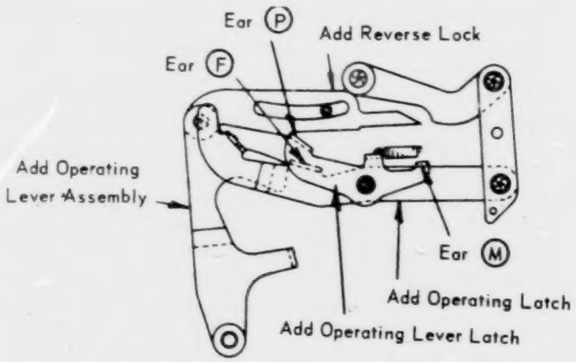
The motor starting assembly, shown in figure 10-28, connects the parallel bar, riding under the multiplier key section, to the motor switch contacts. The parallel bar is moved down when a key is depressed. The sum of the movements of the linkage causes the tip of the switch operating link to drawaway from the points, which are spring closed. The motor then starts and, through the drive train illustrated in figure 10-11, turns the restore idler drive gear, figure 10-29, which will engage the multiplying mechanism to the motor.

When the parallel bar moved down it operated the mechanism shown in figure 10-29 causing the starting control lever to raise the setting clutch opening lever into engagement with the teeth of the restore drive idler gear. The effect of the gear moving the setting clutch opening lever is shown in figure 10-30. The lever lifts the setting clutch release dog out of engagement with the setting clutch, leaving the clutch free to turn.


Add Operating Lever Assembly
Keyboard Clear Shaft Assembly
Power Add Restore Link

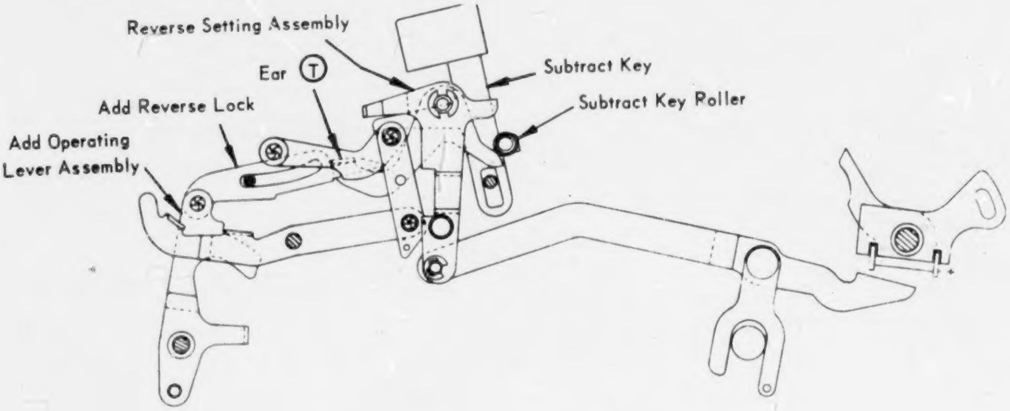
91.613

Figure 10-24. — Operating lever relatching.


Ear Ⓟ
Add Reverse Lock
Ear Ⓕ
Add Operating Lever Assembly
Ear Ⓜ
Add Operating Latch
Add Operating Lever Latch

91.614

Figure 10-25. — Add operating lever.


Reverse Setting Assembly
Ear Ⓣ
Subtract Key
Subtract Key Roller
Add Reverse Lock
Add Operating Lever Assembly

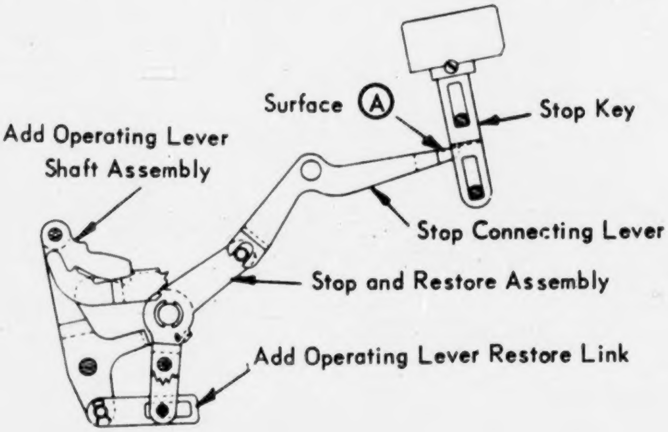
91.615

Figure 10-26.—Subtract bar.

The setting clutch can now drive the multiplier selection mechanism shown in figure 10-30.

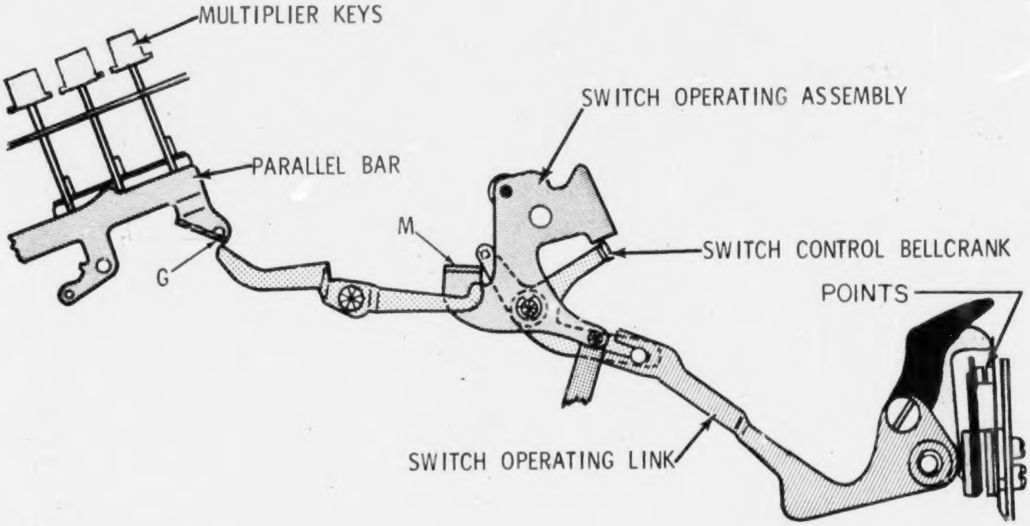
On the shaft with the setting clutch is the selection setting cam. When this cam turns with the setting clutch, it raises the selection setting bellcrank in the multiplier selection mechanism. As the bellcrank moves it causes a floating link on the selection setting arm to engage lug B on the selection bar. Further rotation of the selection setting arm pulls the selection bar to the left (front of the machine) until one of its lugs stops against the end of a depressed key. As you can see, the amount of motion of the bar will depend on which key is depressed.

As the selection bar moves to the left, the hook G on its end will haul back the selection segment a distance which represents one cog for each unit in the number selected on the keyboard. The trip unit pawl does not impede the movement of the trip unit gear or selection segment, since it was raised by the trip pawl release link at the beginning of the setting cycle. Once the selection segment is positioned, the trip unit pawl again engages the gear, locking it in the selected position.


Surface Ⓐ
Stop Key
Add Operating Lever Shaft Assembly
Stop Connecting Lever
Stop and Restore Assembly
Add Operating Lever Restore Link

91.616

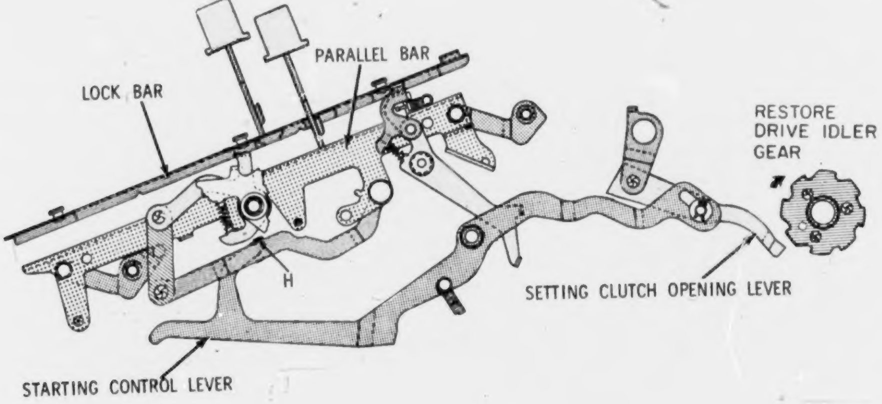
Figure 10-27.—Add operating lever restore.


MULTIPLIER KEYS
SWITCH OPERATING ASSEMBLY
PARALLEL BAR
M
SWITCH CONTROL BELLCRANK
G
POINTS
SWITCH OPERATING LINK

91.621

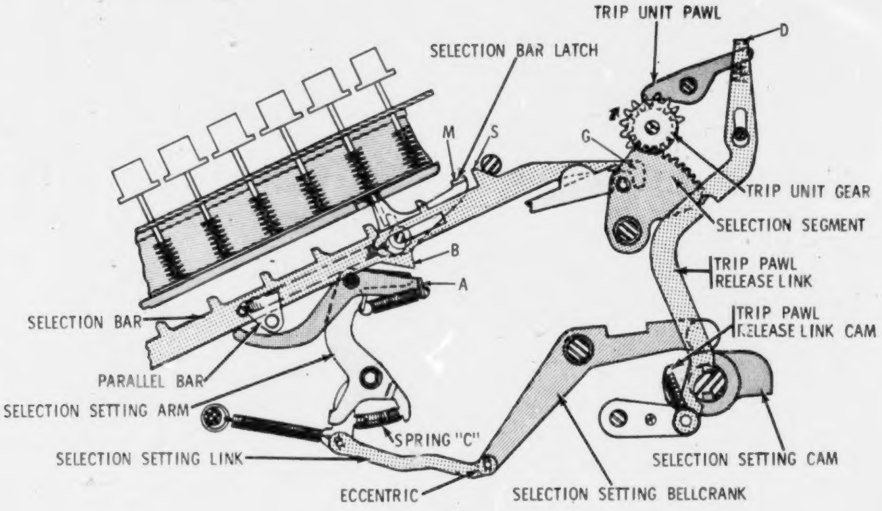
Figure 10-28.—Motor starting assembly.

To achieve multiplication, by any number except zero, the main clutch must be engaged and rotated. A main clutch starting cam is mounted on the shaft with the setting clutch, (fig. 10-31). When the setting clutch was released, the starting cam operated the linkage to the main clutch release dog, figure 10-32. The main clutch release dog is tipped out of engagement with the main clutch, and held out of engagement by the roller on the main clutch latch until the multiplication is accomplished. Releasing the main clutch dog causes the clutch


PARALLEL BAR
LOCK BAR
RESTORE
DRIVE IDLER
GEAR
H
SETTING CLUTCH OPENING LEVER
STARTING CONTROL LEVER

61.622

Figure 10-29.—Setting release mechanism.

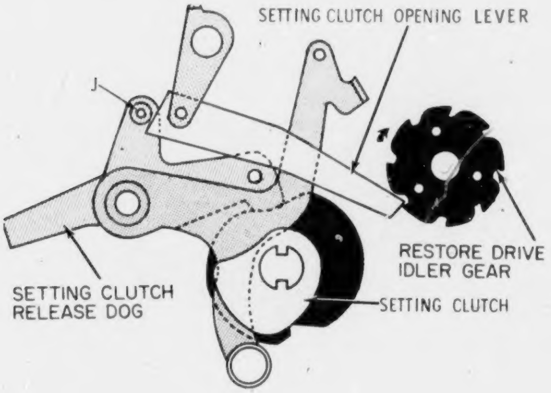

TRIP UNIT PAWL
D
SELECTION BAR LATCH
M
S
G
TRIP UNIT GEAR
SELECTION SEGMENT
TRIP PAWL RELEASE LINK
TRIP PAWL RELEASE LINK CAM
B
A
SELECTION BAR
PARALLEL BAR
SELECTION SETTING ARM
SPRING "C"
SELECTION SETTING LINK
SELECTION SETTING CAM
ECCENTRIC
SELECTION SETTING BELLCRANK

91.623

Figure 10-30.—Multiplier selection mechanism.

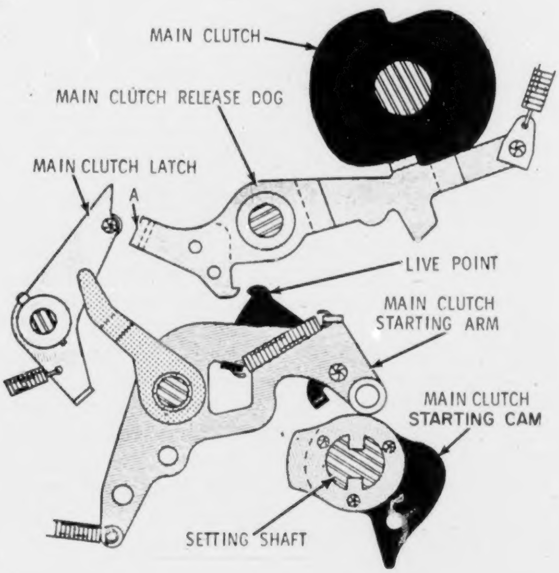
to engage with the clutch shaft, and leaves it free to turn. This released position can be seen in figure 10-35.

Each cycle of the main clutch adds the numbers set in the keyboard to the middle dials on the carriage. A main clutch cycle is achieved when the clutch rotates 180°. The two-tooth gear, seen in figure 10-33, is connected to the main clutch shaft. Through this gear the main clutch moves the selection segment back one tooth for each cycle. When the selection segment approaches its normal, or zero, position, it operates a linkage to disengage and lock the main clutch and stop the multiply cycle.


SETTING CLUTCH OPENING LEVER
J
RESTORE DRIVE IDLER GEAR
SETTING CLUTCH RELEASE DOG
SETTING CLUTCH

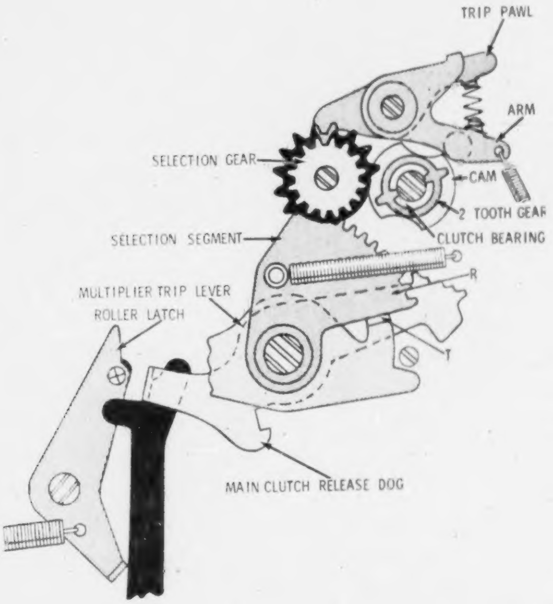
91.624

Figure 10-31.—Setting release.


MAIN CLUTCH
MAIN CLUTCH RELEASE DOG
MAIN CLUTCH LATCH
A
LIVE POINT
MAIN CLUTCH STARTING ARM
MAIN CLUTCH STARTING CAM
SETTING SHAFT

91.625

Figure 10-32.—Main clutch assembly.

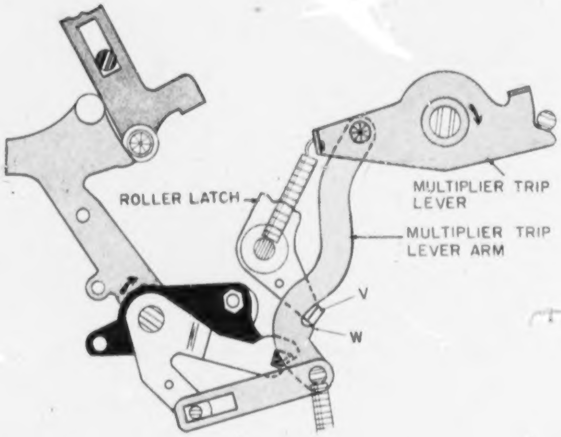

TRIP PAWL
ARM
SELECTION GEAR
CAM
2 TOOTH GEAR
CLUTCH BEARING
SELECTION SEGMENT
R
MULTIPLIER TRIP LEVER
ROLLER LATCH
T
MAIN CLUTCH RELEASE DOG

91.626
Figure 10-33.—Multiplier selection gears.

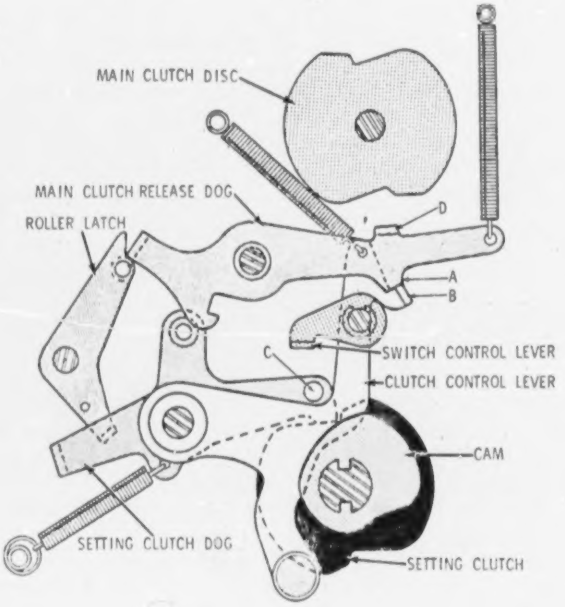
For the restore operation to begin the main clutch must be disengaged, and the setting clutch dog must be disengaged, so the setting clutch can operate. These conditions are obtained as point R (fig. 10-33) on the selection segment presses down against ear T on the multiplier trip lever. The motion of the trip lever can be seen in figure 10-34, where the lip W on the lever link pulls up on ear V of the roller latch, causing the latch to disengage the main clutch release dog. The release dog is returned to engage the main clutch by the springs which can be seen in figure 10-35. When the dog is seating in the main clutch, lip A of the release dog disengages ear B of the clutch control lever, which in rising against stud C of the setting clutch dog, releases the setting clutch. As the setting shaft turns, the dip control cams which were shown in figure 10-12 turn and raise the carriage. As the carriage raises it disengages the selection idler gears from the pivot gears.

Locking Down of Keys

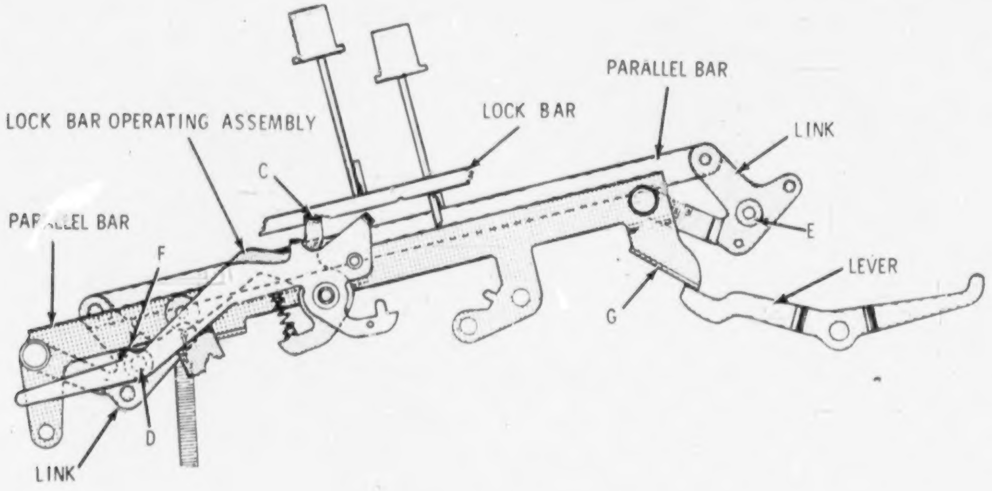
Omitted from the preceding description was the process by which the multiplier key is held down during the multiplier operation, and then released in the restore operation.


ROLLER LATCH
MULTIPLIER TRIP LEVER
MULTIPLIER TRIP LEVER ARM
V
W

91.627
Figure 10-34.—Multiplier trip assembly.


MAIN CLUTCH DISC
MAIN CLUTCH RELEASE DOG
ROLLER LATCH
D
A
B
SWITCH CONTROL LEVER
C
CLUTCH CONTROL LEVER
CAM
SETTING CLUTCH DOG
SETTING CLUTCH

91.628
Figure 10-35.—Setting clutch assembly.



91.629

Figure 10-36.—Parallel bar assembly.

Before a multiplier key is depressed, the lockbar is held to the rear by a spring. When the lockbar is in this position any multiplier key can be depressed. The effect of depressing a key can be seen in figure 10-36. When the keystem forces the parallel bar down, the bar contacts ear F of the lockbar operating assembly. As the lever in this assembly is tilted downward it operates a second lever through a spring; the second lever has live point C which presses the lockbar toward the front of the machine, and the key is locked down. In this position the lockbar not only holds the depressed key, but also prevents any other multiplication key from being depressed.

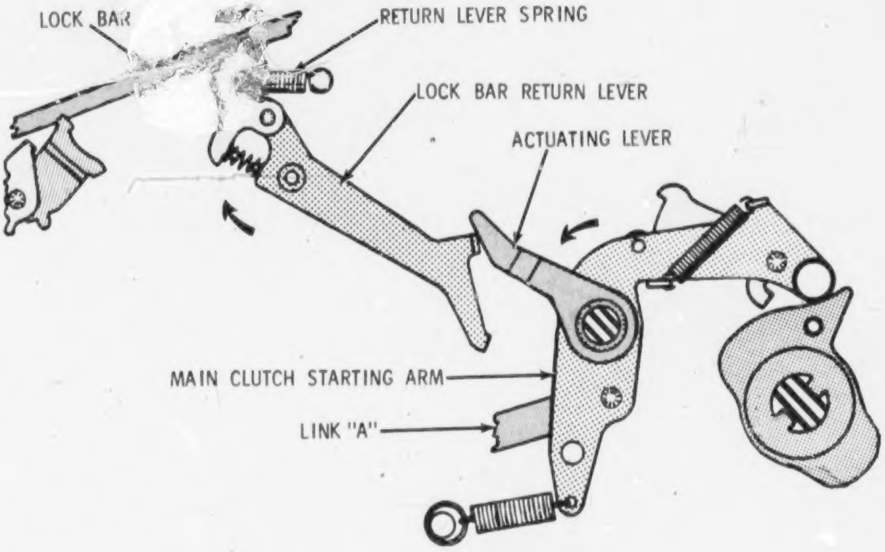
The depressed key is released late in the setting clutch phase of the multiplication cycle, by means of the mechanism illustrated in figure 10-37. This system of levers is driven by the main clutch starting cam and pulls the lockbar toward the rear of the machine to release the keystem. The key then rises from the pressure of the keystem spring.

As the main clutch starting arm rotates it also pulls link A, as seen in figure 10-37. The other end of this link can be seen in figure 10-38. Motion of link A causes the parallel bar return lever to turn, and it engages the roller on the arm which pivots on the adjustable stud. Until the multiplier key is released the effect of this motion is to place tension on the spring between link A and the parallel bar return lever. When the key is released the combined efforts of (1) the spring at the rear part of the parallel bar and (2) the spring on the parallel bar return lever cause the bar to return to its original position.

When the setting clutch is in operation the selection bar, figure 10-29, is retained by the selection bar latch to prevent its being operated by an accidental depression of a multiplier key. When the lockbar moves toward the front of the machine, it raises the selection bar latch to free the selection bar. By this means the selection bar will only be operated after the desired multiplier key is fully depressed and locked.

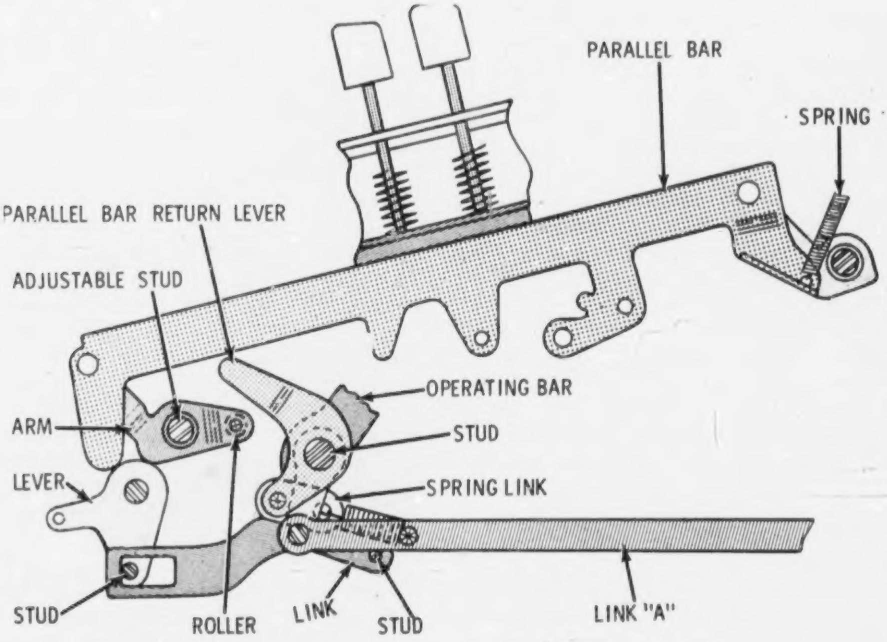
Automatic Shift

At the end of each multiplication cycle the carriage will automatically shift to position for the next number to be multiplied. So that the operator may either enter the numbers of his multiplier from right to left or left to right, the direction control key (#12 in fig. 10-1) can be set to cause the carriage to shift in either direction. The automatic shift is achieved through the shift control assembly, shown in figure 10-39. This assembly is activated by the dip control cam follower on the right side of the machine. (Figure 10-3 shows the cam follower on the left side of the machine, which is why the one in figure 10-39 looks different.)


LOCK BAR
RETURN LEVER SPRING
LOCK BAR RETURN LEVER
ACTUATING LEVER
MAIN CLUTCH STARTING ARM
LINK "A"

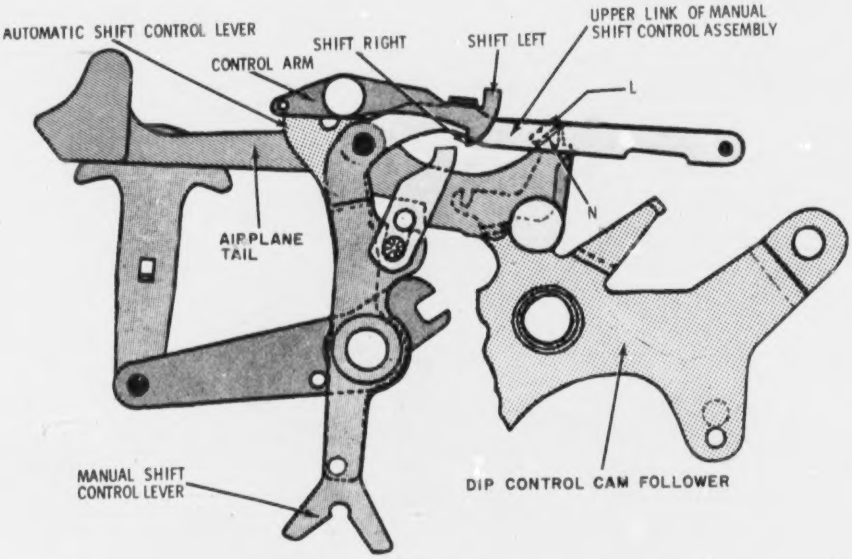
91.630

Figure 10-37.—Lockbar restoring mechanism.


PARALLEL BAR
SPRING
PARALLEL BAR RETURN LEVER
ADJUSTABLE STUD
OPERATING BAR
ARM
STUD
LEVER
SPRING LINK
STUD
ROLLER
LINK
STUD
LINK "A"

91.631

Figure 10-38.—Parallel bar restoring mechanism.


AUTOMATIC SHIFT CONTROL LEVER
CONTROL ARM
SHIFT RIGHT
SHIFT LEFT
UPPER LINK OF MANUAL SHIFT CONTROL ASSEMBLY
L
N
AIRPLANE TAIL
MANUAL SHIFT CONTROL LEVER
DIP CONTROL CAM FOLLOWER

91.632

Figure 10-39.—Shift control assembly.

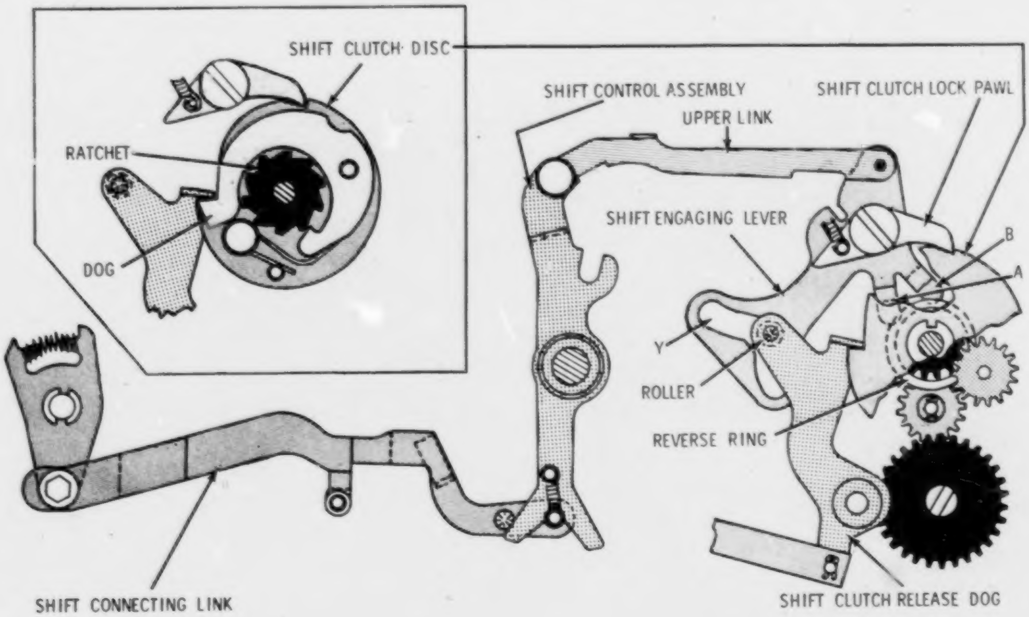
At the end of the cycle, as the carriage is raised by the dip control cams, the live point, (L in fig. 10-39) on the dip control cam follower, contacts surface N on the "airplane tail" and pulls it toward the rear of the machine. The "airplane tail" moves the automatic shift control lever toward the front of the machine.

The position of the control arm on the automatic shift control lever dictates whether the direction of the shift will be to the right or the left. When this arm is pivoted so the upper hook pulls the shift control link the carriage shift will be to the left in the automatic mode. When the arm is pivoted so the lower hook operates the link through the lever, the shift will be reversed. Whether this control lever is up or down depends on the position of the direction control slide on the keyboard. The effect of the manual shift key through this linkage will be the reverse of the effect of the automatic shift input.

Figures 10-40 and 10-41 show how the shift clutch and shift reverse clutch are operated by the control mechanism.

Although of a more simple design the shift clutch is similar in function to the clutches previously described, in that it is held stationary by a dog. When the dog is released the clutch automatically connects to the drive shaft. Included in the assembly is the reverse clutch which selects the direction of rotation of the shift shaft. Movement of the shift engaging lever simultaneously selects the direction of rotation and engages the shift clutch to the drive train.

To see how the direction of motion is selected, compare the views provided by figures 10-40 and 10-41. The shift reversing ring has sloping sides. When the rearward finger of the shift engaging lever (B in fig. 10-40) presses against the ring, it moves the ring to the right as seen in figure 10-41. If the shift engaging lever moved the other way, finger A would move the ring to the left. The lever then frees the shift clutch by means of the Y-shaped slot (Y) rocking the shift clutch release dog. When the shift reverse ring moves to the right it carries the shift reverse pin with it into engagement with the shift reverse gear to the right. The shift reverse gears and shift reverse pin act as a dog clutch. The shift reverse gear (left) drives the shift idler through the idler shift reverse double gear. Figure 10-41 shows these gears folded out for clarity. They actually are in constant mesh. When the reversing ring is moved in the opposite direction it causes the pin to engage the shift



91.633

Figure 10-40.—Shift clutch assembly.

reverse gear (right) on the left side. This gear directly drives the shift idler.

Figure 10-42 illustrates the shift drive train. The output from this transmission is through the vertical shift shaft, driven from the shift idler through the jackshaft gears.

Restoring the Shift Mechanism

Restoring of the shift mechanism is initiated by the restart cam mounted on the shift jackshaft. Rotation of the restart cam produces a clockwise motion of the restart bellcrank which lifts one end of the automatic shift link, or "airplane tail". The other end of the "airplane tail" goes down and disengages from the live point on the dip control cam follower. You can see this effect in figure 10-43, and by referring to figure 10-39.

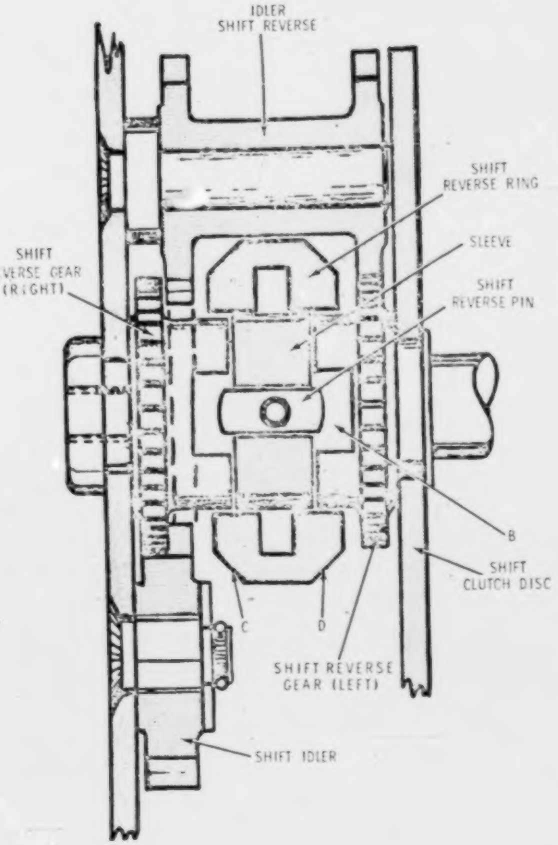
Multiplier Zero Shift

When the "O" key in the multiplier unit is depressed the carriage shifts one position without entering the numbers from the keyboard dials to the middle dials. To do so the main clutch must be prevented from turning, since turning would transfer the keyboard data to the carriage.

When the zero key is depressed it operates the parallel bar to start the motor and engage the setting clutch, and it also operates the main clutch disabling beam. The main clutch disabling mechanism is shown in figure 10-44. When the key is depressed the zero key bellcrank moves the end of the disabling beam down; the other end of the beam rises, causing hook C on its end to disengage ear D on the main clutch disabling bail. Surface E on the disabling bail contacts ear F on the live point mounted on the main clutch starting arm. With the live point held in the hook of the main clutch release dog, the dog will not move into position to release the clutch. This sequence of operations will become clear if you refer to figure 10-32. When the main clutch is disabled, and the setting clutch activated in the normal manner by the action of the parallel bar, a cycle will be completed and a shift will occur.

Nonshift Key

The purpose of the nonshift key is to lock out the automatic shift figure. When the nonshift key is depressed the lever W in figure 10-45 tips, causing the stud X to contact the diagonal surface of the nonshift operating bail and force the bail forward. The bail tilts the nonshift control lever counterclockwise, and through the interponent, raises the end of the


IDLER
SHIFT REVERSE
SHIFT
REVERSE RING
SLEEVE
SHIFT
REVERSE PIN
SHIFT
VERSE GEAR
(RIGHT)
B
SHIFT
CLUTCH DISC
C
D
SHIFT REVERSE
GEAR (LEFT)
SHIFT IDLER

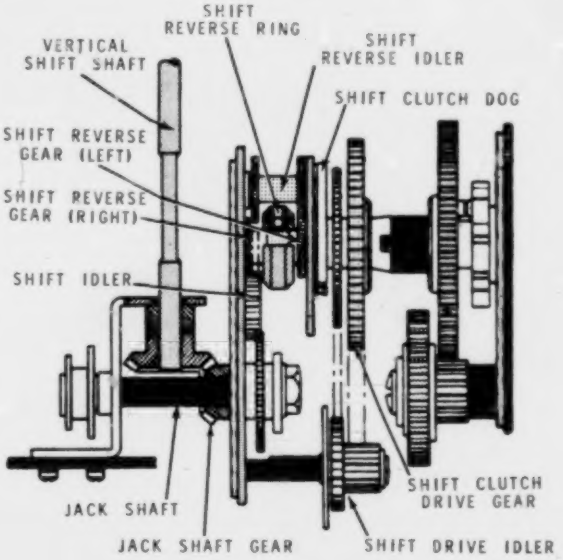
91.624

Figure 10-41.—Shift clutch.

"airplane tail" so that the nose Y will not contact the ear of the livepoint T on the carriage positioning link, and the automatic shift mechanism is interrupted.

Nonshift Control During Addition and Subtraction

Ear N of the add operating lever, figure 10-46, disables the shift by lowering the front end of the nonshift control lever. The nonshift control lever extension rocks the "airplane tail" clockwise, lowering tip Y from the path of ear R on the carriage positioning lever. When the nonshift control lever moves to its nonshift position, it rocks the nonshift operating bail, permitting the nonshift latch to drop behind ear S on the bail. This mechanism is then held in the nonshift position after the add operating lever is latched. (See fig. 10-47 on page 300).


SHIFT
REVERSE RING
SHIFT
REVERSE IDLER
VERTICAL
SHIFT SHAFT
SHIFT CLUTCH DOG
SHIFT REVERSE
GEAR (LEFT)
SHIFT REVERSE
GEAR (RIGHT)
SHIFT IDLER
SHIFT CLUTCH
DRIVE GEAR
JACK SHAFT
JACK SHAFT GEAR
SHIFT DRIVE IDLER

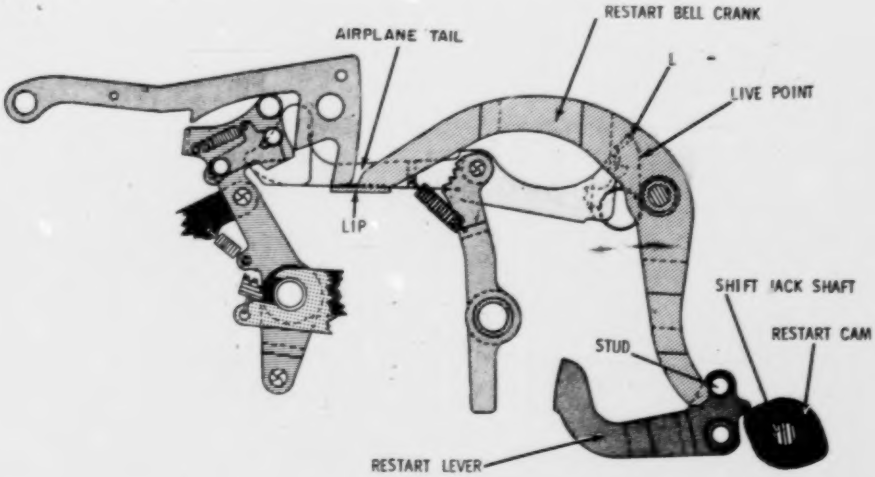
91.635

Figure 10-42.—Shift clutch assembly.

Negative Multiply

When the negative multiply key is depressed it reverses the normal multiplication process by engaging the reverse clutch in the main clutch unit (fig. 10-8). The initial action of the negative multiplier key can be seen in figure 10-47. When the key is depressed lip B depresses the end of the negative reverse lever, and a counter action of this lever on the bellcrank pulls the reverse setting bar toward the front of the machine. When the key is depressed it is latched down by the mechanism shown in figure 10-48. The key latch hooks over a near shown formed by the turned-over end of the keystem. (See fig. 10-48 page 301).

The reverse setting bar assembly is shown in figure 10-49. As this assembly is drawn toward the front of the machine the reverse operating fork positions the reverse clutch for negative operation. The negative multiplier key can be locked down so that negative multiplying operations will be repeated. The locking system is shown in figures 10-47 and 10-48. To lock the machine in negative operation, depress the repeat negative multiply key. This key will depress the negative multiply key and its associated


AIRPLANE TAIL
RESTART BELL CRANK
L
LIVE POINT
LIP
SHIFT JACK SHAFT
RESTART CAM
STUD
RESTART LEVER

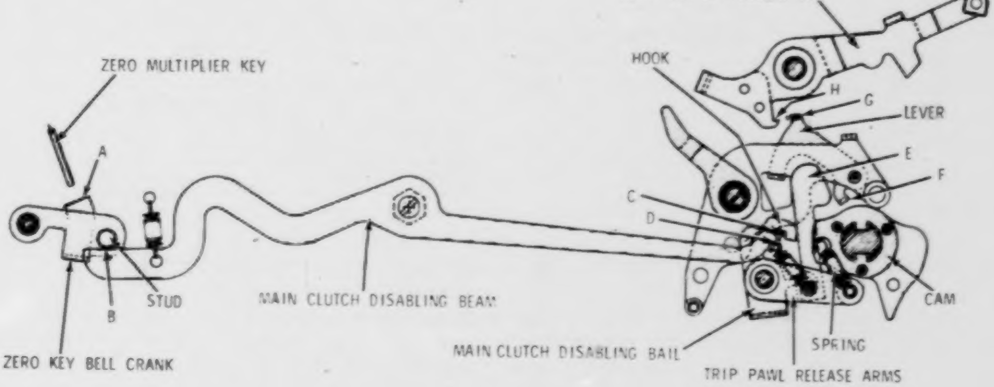
91.636

Figure 10-43.—Shift control lever assembly.

linkage will operate to reverse the clutch action. The repeat key also engages latch D, figure 10-47, with ear C. This latch will hold down the negative multiply key until the stop key is depressed or the carriage return is activated. (See 10-49 pg. 302)

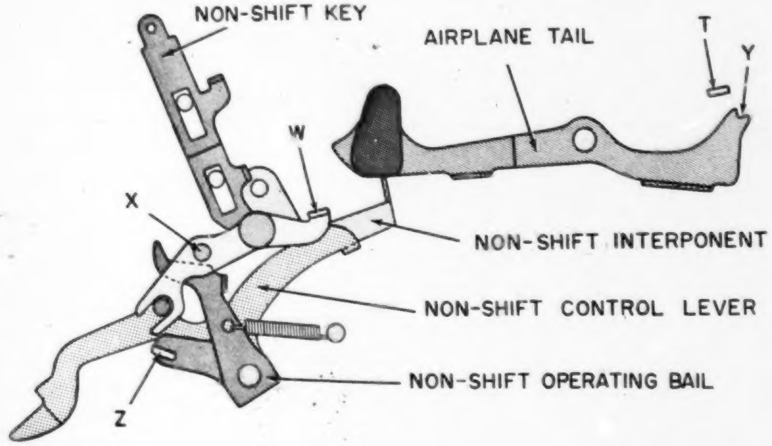
When the stop key, figure 10-48, is depressed the tail of the connecting lever goes down. The bent section E on the end of the lever raises lip F of the repeat key latch, which in turn releases the repeat key. Meanwhile the fork at the end of the stop connecting lever raises the stud on the end of the release lever. The release lever presses against the negative multiplier key latch at point G. As a result the key latch rotates clockwise, and its shoulder H disengages the ear J at the end of the negative multiplier key, and the key returns to position.

The way the carriage return key releases the repeat negative multiplier key is shown in figure 10-50. When the key is depressed it rotates the


MAIN CLUTCH RELEASE DOG
ZERO MULTIPLIER KEY
HOOK
H
G
LEVER
A
E
F
C
D
STUD
B
MAIN CLUTCH DISABLING BEAM
CAM
SPRING
MAIN CLUTCH DISABLING BAIL
ZERO KEY BELL CRANK
TRIP PAWL RELEASE ARMS

91.637

Figure 10-44.—Zero shift.


NON-SHIFT KEY
AIRPLANE TAIL
T
Y
W
X
NON-SHIFT INTERPONENT
NON-SHIFT CONTROL LEVER
NON-SHIFT OPERATING BAIL
Z

91.638

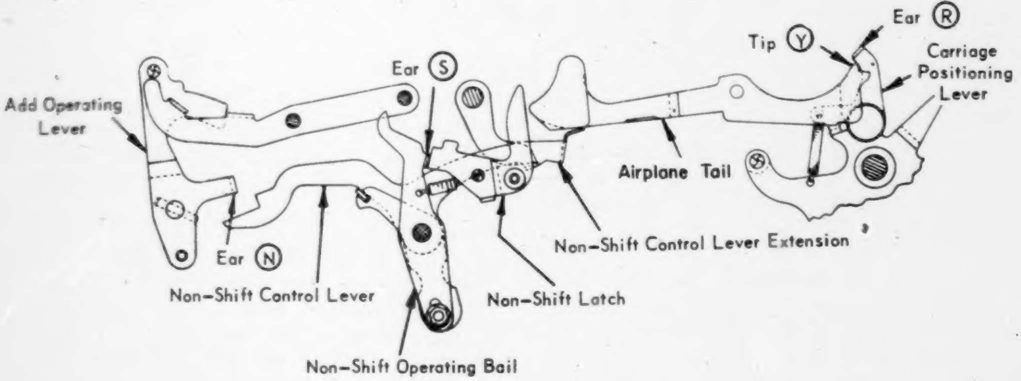
Figure 10-45.—Nonshift.

latch release lever counterclockwise. The release lever operates the repeat key latch to disengage the repeat negative multiplier key, and the negative multiplier key latch to release the negative multiplier key.

REMOVAL OF THE MULTIPLIER KEY SECTION.—Remove the binding screw at the front and rear of the key section. Lift the multiplier key section up and out of the machine.

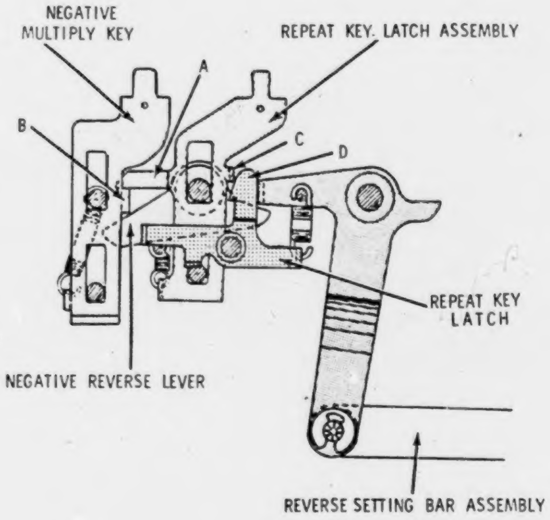
REPLACEMENT OF THE MULTIPLIER KEY SECTION.—Place the key section in the machine. Move the top of the lockbar return lever, figure 10-37, toward the front of the machine with a spring hook, allowing the rear end of the key section to move down slightly. Raise up the lip on the selection bar latch, figure 10-30, and the key section will now drop into place. Replace the binding screws at the front and rear of the key section.

ADJUSTMENT OF THE MULTIPLIER KEY SECTION.—If the multiply keystem lockbar is released too soon, a depressed multiplier key will rise and in this position will fail to stop the multiplier selection bar. The selection bar


Ear (R)
Tip (Y)
Carriage Positioning Lever
Ear (S)
Add Operating Lever
Airplane Tail
Non-Shift Control Lever Extension
Ear (N)
Non-Shift Control Lever
Non-Shift Latch
Non-Shift Operating Bail

91.639

Figure 10-46.—Nonshift control.



91.640

Figure 10-47.—Negative multiply key.

will be driven to the front of the machine, resulting in an overselection.

Check by depressing the # 5 multiplier key and operate the machine by hand until the multiplier trip unit has been positioned and the multiplier trip unit pawl reseats into the gear of the trip unit. As the pawl enters the trip unit gear the actuating lever, figure 10-36, on the main clutch, starting arm assembly should just begin to return the top ear on the lockbar return lever. Form the ear on the lockbar return lever as required for proper return timing.

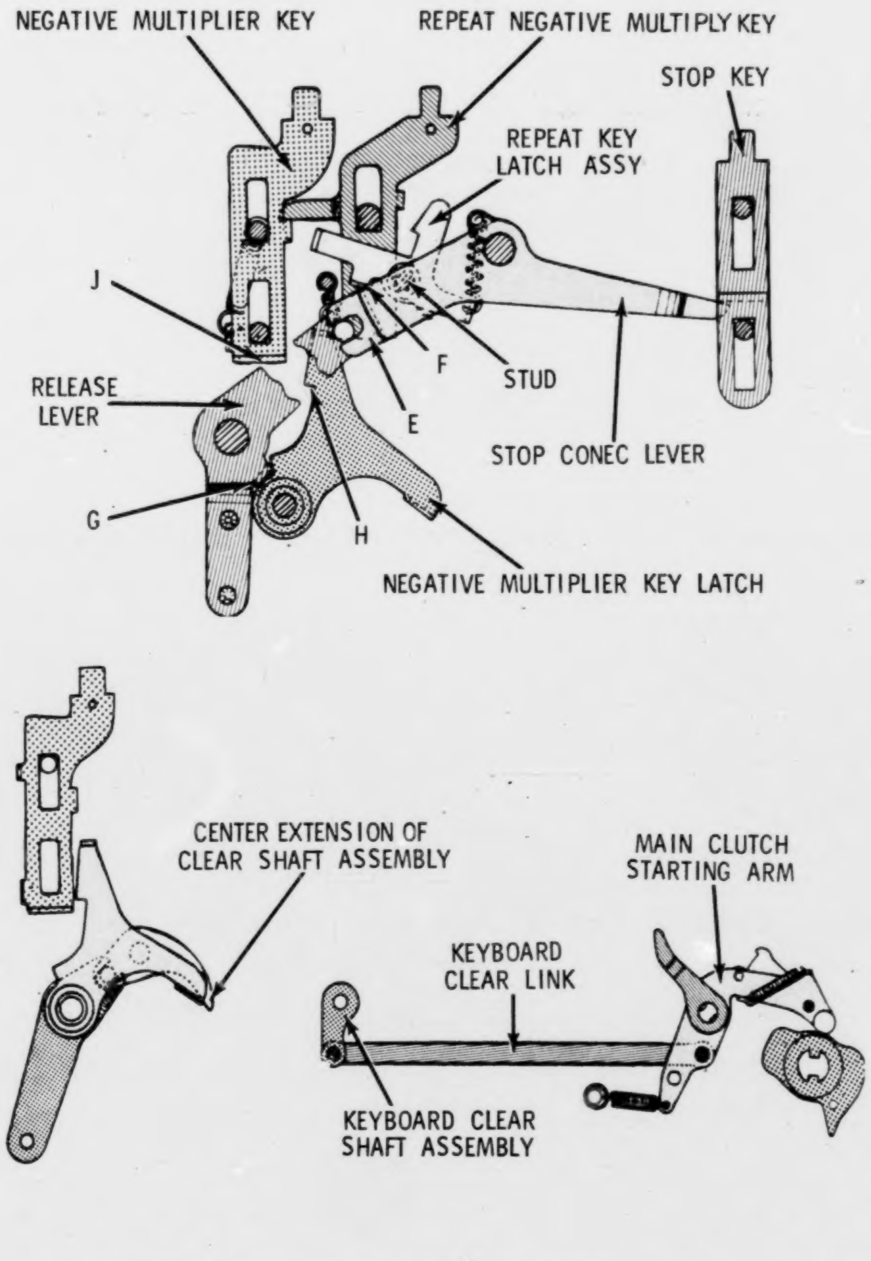
If the selection bar is not positioned and stopped properly when a multiplier key is depressed, the selection segment will overthrow or underthrow the multiplier trip unit gear. Either action will result in an improper selection of all multiplier keys. When the selection bar, figure 10-51, is overselecting, from the rear of the selection bar up; when underselecting, from the rear of the selection bar down.

To test, after the selection bar has been adjusted, depress a multiplier key and operate the machine by hand. The multiplier selection segment should move the multiplier trip unit gear the same number of teeth corresponding to the multiplier key that is depressed and stopped. Then as the multiplier trip unit pawl moves into mesh with the gear, there should be no movement of the gear. The pawl should enter centrally between the teeth of the gear without contacting either side. If one of the keystems is bent, it will cause an overselection or underselection for that individual key. Make certain that the correct adjustment is made.

When the selection bar is binding, the # 1 keystem will get behind the lug on the selection bar when a # 9 key is depressed and will be automatically followed by a quick depression of the #1 key. Form the selection bar as required for free action.

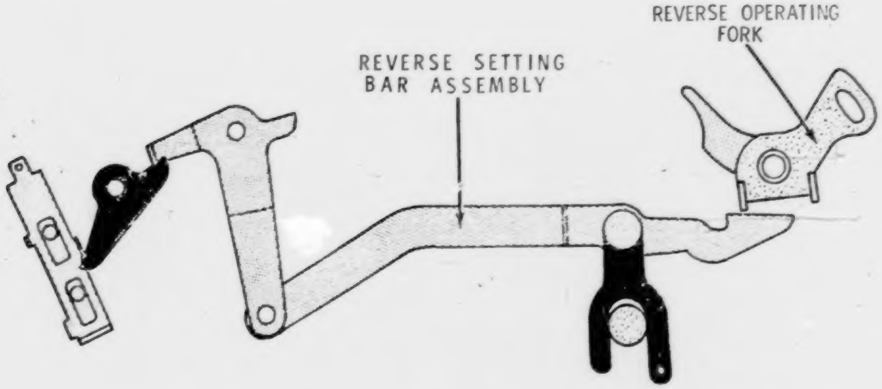
A weak spring C on the multiplier selection setting arm, figure 10-30, will cause the multiplier selection bar not to be driven the required amount to make a # 9 multiply selection. To eliminate this condition, shorten or replace the spring.

MULTIPLIER SELECTION SETTING BELLCRANK ADJUSTMENT.—If there is more than .010 inch clearance between the upper member of the multiplier selection setting arm at point A (fig. 10-30) and the rear of point B on the selection bar, when a # 9 multiplier key is depressed, the machine will register a number 8. With the power off, depress a multiply key and adjust the eccentric on the multiplier selection setting bellcrank for desired clearance. Before


NEGATIVE MULTIPLIER KEY
REPEAT NEGATIVE MULTIPLY KEY
STOP KEY
REPEAT KEY LATCH ASSY
J
RELEASE LEVER
F
STUD
E
STOP CONEC LEVER
G
H
NEGATIVE MULTIPLIER KEY LATCH
CENTER EXTENSION OF CLEAR SHAFT ASSEMBLY
MAIN CLUTCH STARTING ARM
KEYBOARD CLEAR LINK
KEYBOARD CLEAR SHAFT ASSEMBLY

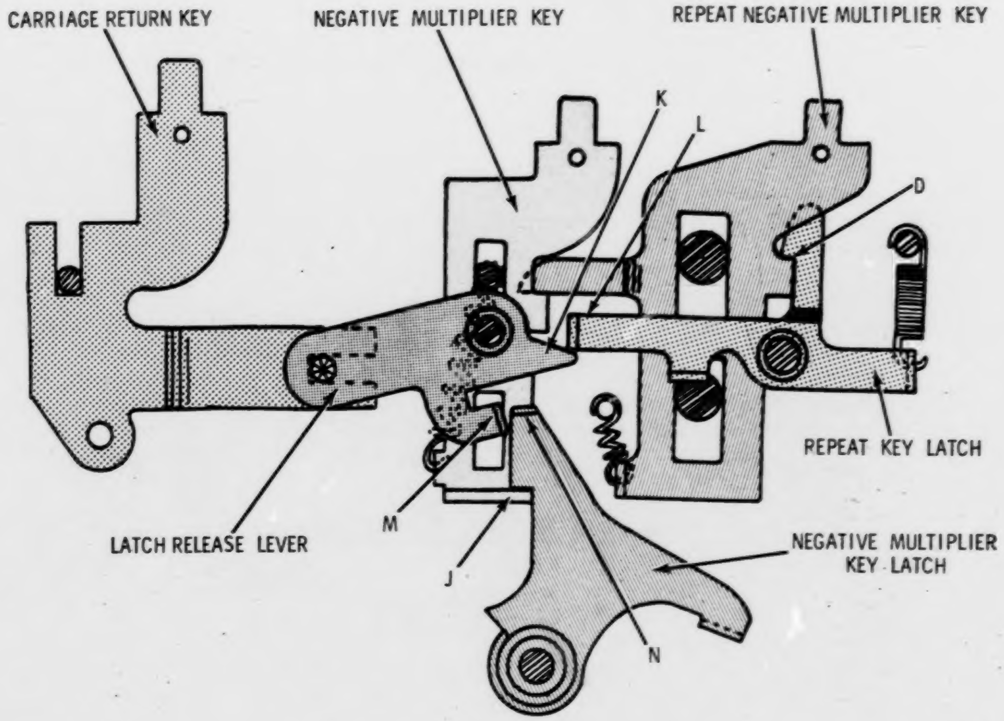
91.641

Figure 10-48.—Negative multiplier key assembly.


REVERSE OPERATING FORK
REVERSE SETTING BAR ASSEMBLY

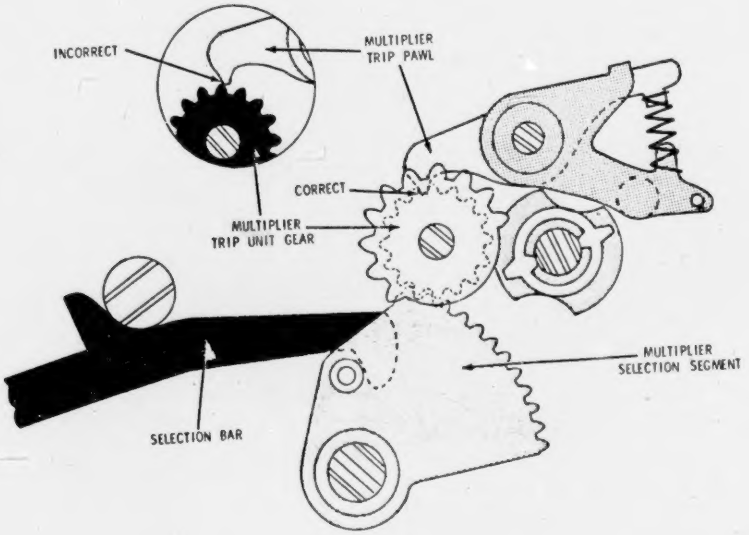
91.642

Figure 10-49.—Negative multiply.


CARRIAGE RETURN KEY
NEGATIVE MULTIPLIER KEY
REPEAT NEGATIVE MULTIPLIER KEY
K
L
D
REPEAT KEY LATCH
LATCH RELEASE LEVER
M
J
NEGATIVE MULTIPLIER KEY LATCH
N

91.643

Figure 10-50.—Tab release of negative multiplier.



91.644

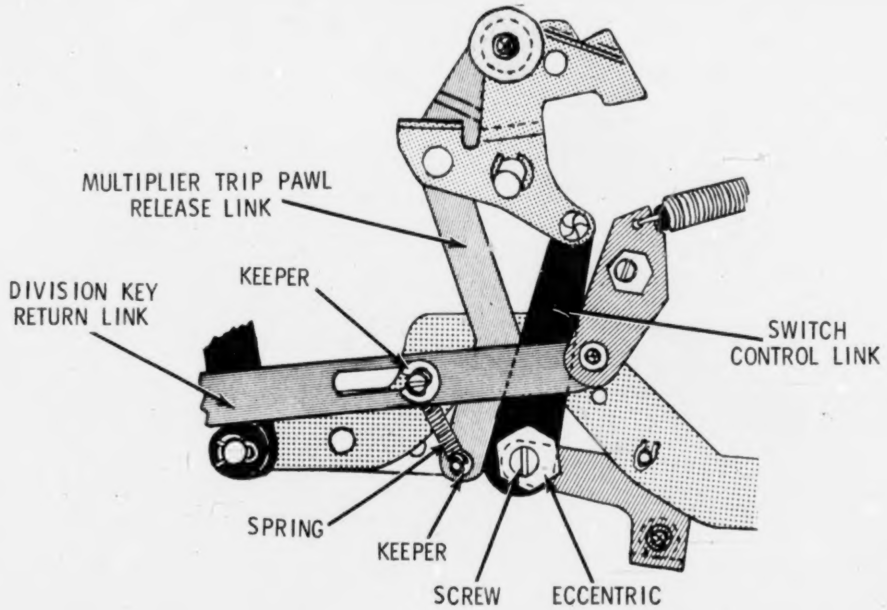
Figure 10-51.—Multiplier trip unit.

forming the selection bar to compensate for throw or replacing the selection setting arm spring, the multiplier selection setting bellcrank adjustment should be checked. The clearance check is the easiest to make.

REMOVAL OF THE RIGHT SETTING LINE BUSHING AND SETTING CLUTCH

Remove the keeper from the division key return link and slip link from stud and upward on top of the stud, figure 10-52. Remove the screw and eccentric from the lower end of the switch control link and remove the switch control link from the switch control bail. Remove the keeper and spring from the lower end of the multiplier trip pawl release link and remove from the multiplier release arm. Remove the screw, lockwasher, and spacer from the right end of the setting shaft (not shown). Remove the keeper (fig. 10-53) from the left dip control cam follower and link to allow the follower to move to the left with the setting shaft. Use a bronze punch and hammer to tap the setting shaft to the left. Be careful not to damage the threads in the holes in the center of the shaft. Remove the left dip control cam follower and link. At this time the main clutch starting cam can be removed from the setting shaft. Then, remove the multiplier pawl release cam spacer and the multiplier selection setting cam. Next, you remove the spacing washer, spring washer and setting clutch assembly. Now, you remove the long spacer, brass washer, and reverse cam. Removal of the setting shaft bearing sleeve completes the disassembly of this unit. To replace the right setting line bushing and setting clutch, reverse the above steps. When replacing the setting clutch assembly cam, make sure the C on the cam is on the right side and to the front of the machine. Also, the letter A on reverse cam goes to the right and up toward the rear of the machine.

There are no adjustments on the setting line and setting clutch, other than to ensure that all parts are replaced properly and not binding. Also check to see that the spring that holds the setting clutch dog is holding the dog in mesh. The multiplier selection setting cam must have the large collar to the right with the high part of the cam to the rear of the machine. The high part of the main clutch starting cam is to the rear of the machine. Place the switch control link eccentric so the stud on the shift control bail will rest lightly against the shift clutch release dog, figure 10-54, or have .001 inch to .003 inch clearance, when the clear release lever is held down.



91.645

Figure 10-52.—Division key return.

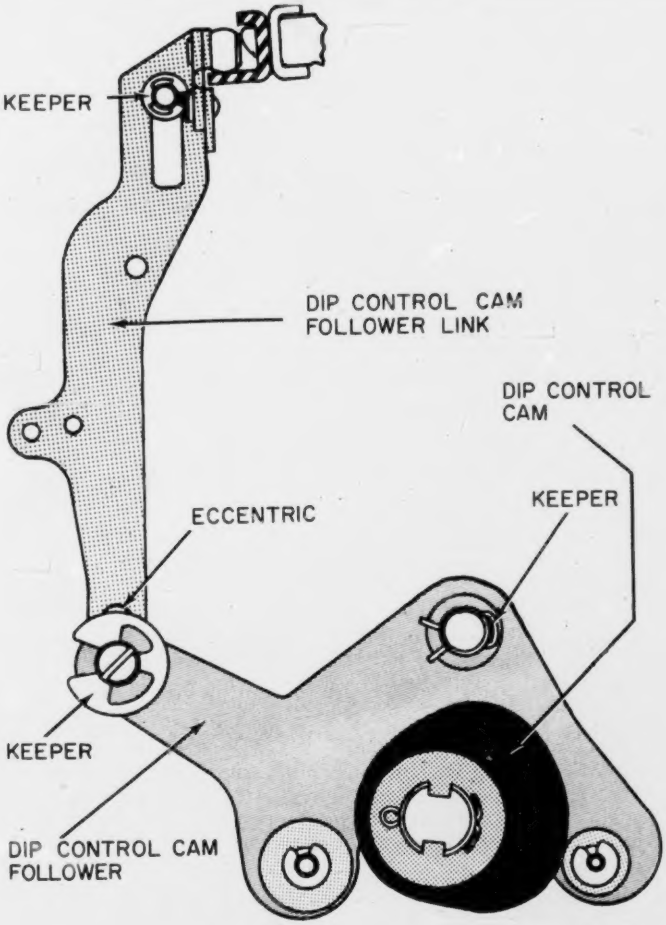
REMOVAL OF SHIFT CLUTCH ASSEMBLY

Remove the starting switch assembly after removing the two binding screws. From the right side, remove the long screw (fig. 10-55) that holds the switch operating link and spacers in place. Remove switch operating link and spacers. Do not lose the small spacer in the switch operating link.

Remove the shift drive idler assembly after removing the keeper from inside the shift drive idler shaft. Work the shaft out to the right and unkook the spring from the shaft. Lift the shaft drive idler assembly out of the machine. Notice that the shaft is half round at the end and fits into a half-round hole in the side frame. On reassembly be sure that the slotted end of the shift drive idler plate goes between the hub of the shift clutch release dog and small spacer. Remove the lockscrew and drive-adjusting eccentric nut. Remove the binding screw and retainer from the shift clutch shaft. Remove the shift clutch shaft by unscrewing it with a large screwdriver and pulling it out. Remove the drive adjustment lever assembly, spacer washer, drive idler, shift clutch drive gear and ratchet assembly. The shift clutch can now be removed. Do not lose the shift reverse pin, figure 10-56, that is in the shaft on the reverse ring. To replace the shift clutch assembly, reverse the disassembly procedure.

ADJUSTMENT OF THE SHIFT CLUTCH ASSEMBLY

Figure 10-56 gives an exploded view of the shift clutch assembly. When replacing the shift clutch disc assembly, be sure to time it with the shift reverse ring and shaft reverse gear (right) by aligning the notch of groove A with groove B. Make sure that the shift reverse pin is properly located in the shift reverse ring. Slip the shift reverse ring and shift reverse pin over grooves B and note that, when sliding, the shift reverse pin will enter freely in the notches of grooves A and B. Align the notch of the shift reverse gear (right) with grooves A and B so that the shift reverse pin will slide into the notches of the shift reverse gear (right) and grooves A and B. Hold the assemblies together and insert a straightened paper clip (as a timing pin) through the timing hole in the shift clutch disc assembly, through the shift reverse ring and between two teeth of the shift reverse gear



91.646

Figure 10-53.—Carriage positioning.

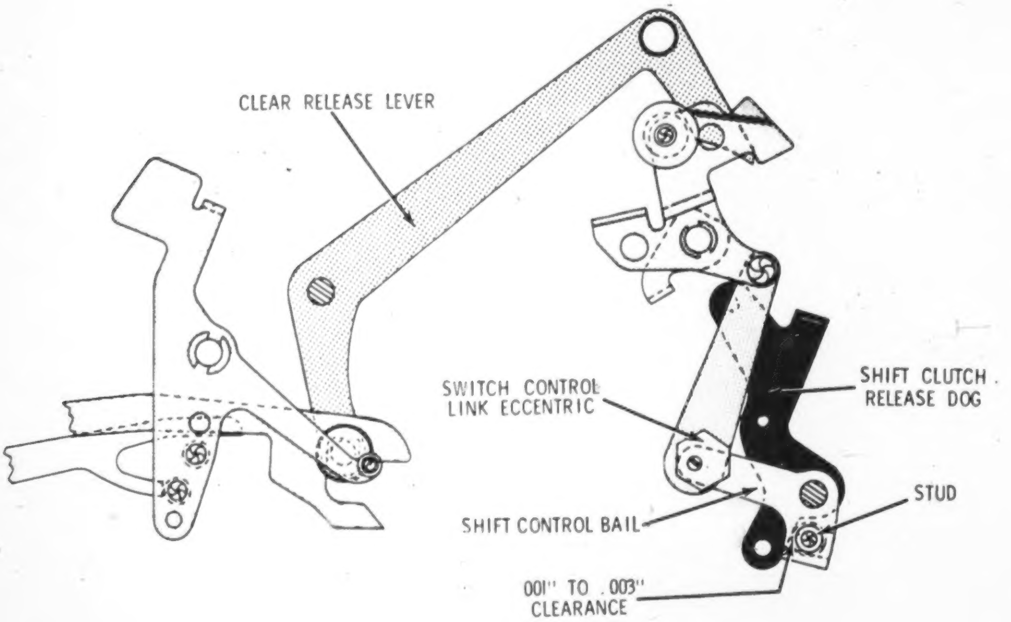
(right), allowing the pin to extend about 1/4 inch through the shift reverse gear (right). Hold the assemblies together with the pin and place them into the machine simultaneously with the shift reverse idler, so that the pin will enter the timing hole in the drive unit frame. (The jackshaft should be in time.) Hold the assemblies in place and replace all parts that were removed in the preceding steps. After parts have been replaced, remove the timing pin toward the inside of the machine.

REMOVAL OF MAIN CLUTCH ASSEMBLY

To remove the main clutch assembly, mark the position of the eccentric and remove the eccentric screw and nut from the rear end of the starter switch interlock, figure 10-57. The mark will eliminate the necessity for an adjustment. Push down on the rear end of the product and counter dial clear link lever and tab lever. Remove the two screws from the trip unit and lift out. Raise up on the starter switch interlock and remove the shaft from the main clutch and lift out the main clutch assembly.

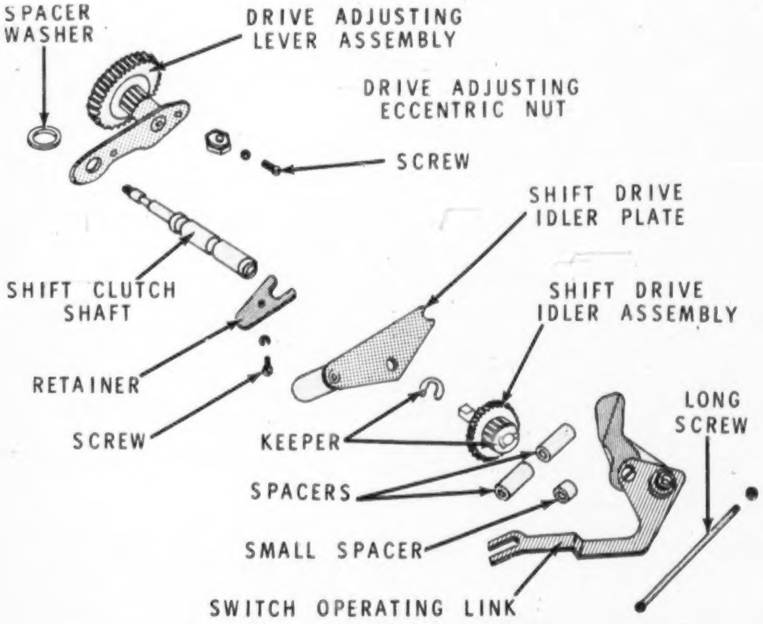
REPLACEMENT OF MAIN CLUTCH ASSEMBLY

Unhook the spring on the main clutch centralizer and push the roller up and to the front of the machine. Replace the main clutch assembly in the machine and insert the shaft. Replace the multiplier trip pawl unit. Push the multiplier selection segment to the rear. NOTE: The


CLEAR RELEASE LEVER
SWITCH CONTROL LINK ECCENTRIC
SHIFT CLUTCH RELEASE DOG
STUD
SHIFT CONTROL BAIL
.001" TO .003" CLEARANCE

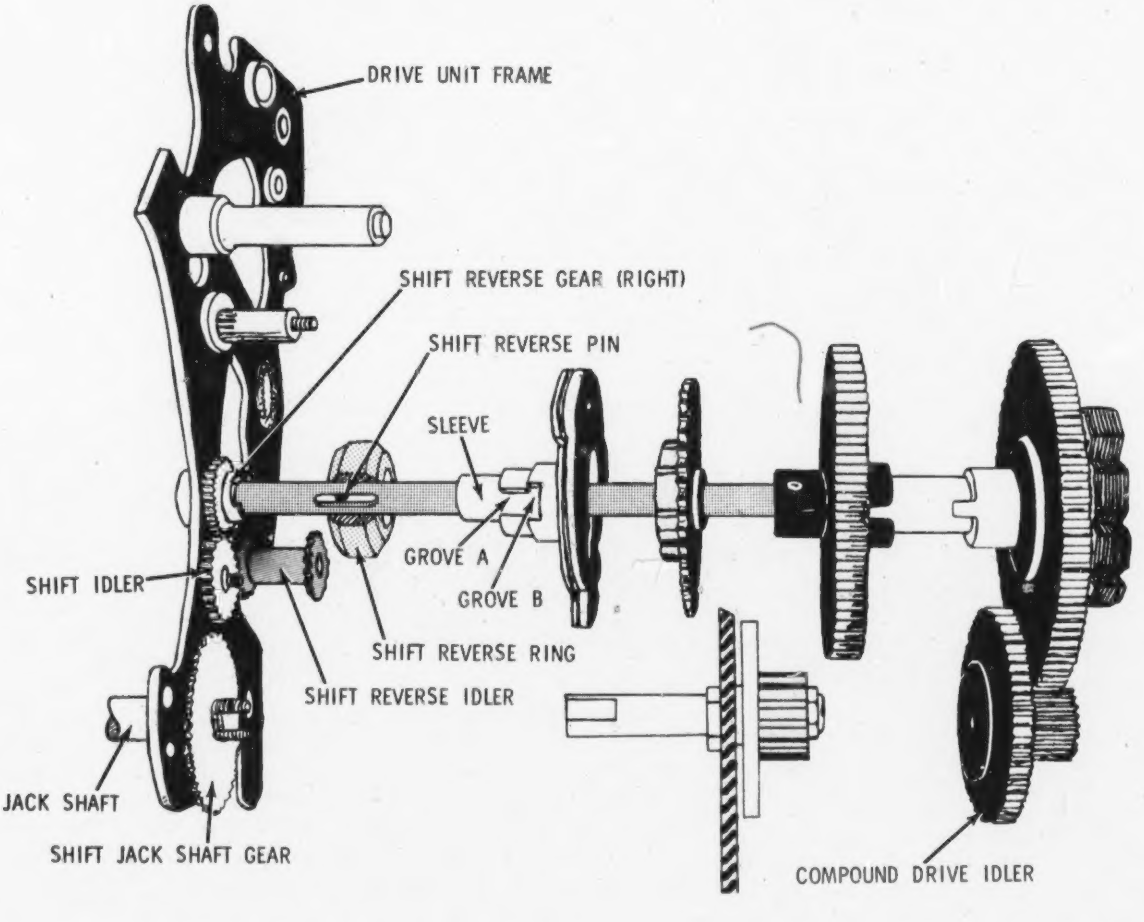
91.647

Figure 10-54.—Shift interlock.


SPACER WASHER
DRIVE ADJUSTING LEVER ASSEMBLY
DRIVE ADJUSTING ECCENTRIC NUT
SCREW
SHIFT DRIVE IDLER PLATE
SHIFT CLUTCH SHAFT
SHIFT DRIVE IDLER ASSEMBLY
RETAINER
LONG SCREW
SCREW
KEEPER
SPACERS
SMALL SPACER
SWITCH OPERATING LINK

91.648

Figure 10-55.—Shift drive idler assembly.


DRIVE UNIT FRAME
SHIFT REVERSE GEAR (RIGHT)
SHIFT REVERSE PIN
SLEEVE
GROVE A
GROVE B
SHIFT IDLER
SHIFT REVERSE RING
SHIFT REVERSE IDLER
JACK SHAFT
SHIFT JACK SHAFT GEAR
COMPOUND DRIVE IDLER

91.649

Figure 10-56.—Shift clutch assembly.

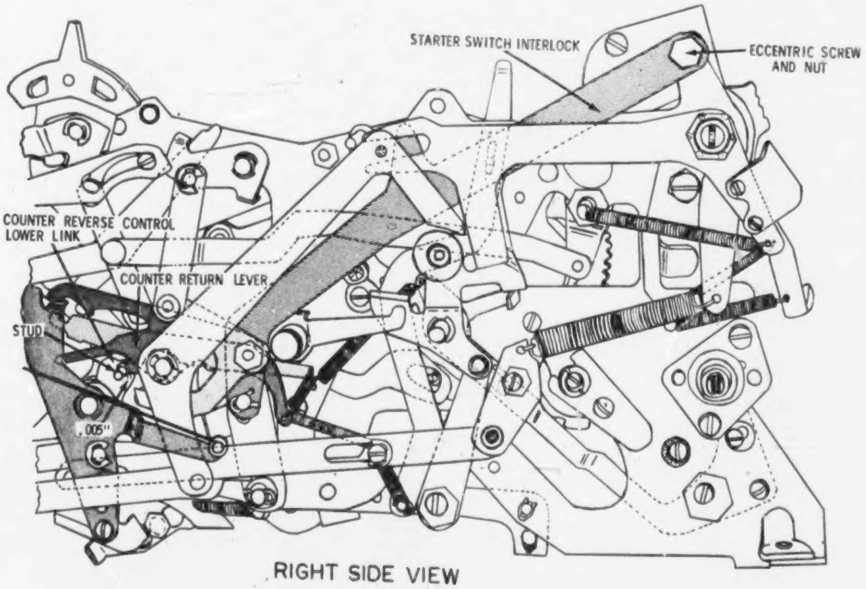


Figure 10-57.—Control section.

91.650

multiplier trip pawl gear has a timing mark. To time, place the pawl in mesh with the timing mark on the gear and hold in this position while placing in machine. Also make sure that the flat part of the main clutch assembly shaft fits into the half-round hole in the multiplier trip pawl unit. Replace the two binding screws. Check to see that the pawl on the multiplier trip pawl unit is in mesh with the timing mark on the gear to ensure that the multiplier trip pawl unit is in time. Hook up the spring on the main clutch centralizer. Replace the eccentric screw in the starter switch interlock. Adjust the eccentric until there is a .005 inch clearance between the heel on the counter return lever and the stud on the counter release control lower link, in normal position.

CLEANING CALCULATORS

The decision to use a cleaning agent or bath on a calculator is not made until the covers have been removed and the internal parts cleaned with low pressure air. Then, the machine is operated by hand to determine whether an aerosol penetrant/lubricant will free up the action of mechanism. If the machine is so sticky or gummy that operation is still impaired, then a cleaning agent or bath is required.

To clean a calculator with a cleaning agent or bath, remove rubber parts and electrical components. Use a spray, agitator, or ultrasonic bath. Rinse all excess cleaning agent and dry the machine well. After cleaning the calculator, lubricate it according to the manufacturers specifications.

CHAPTER 11

OTHER OFFICE EQUIPMENT

As an Instrumentman you will be assigned to disassemble, clean, reassemble, troubleshoot, and repair adding machines, addressographs, cash registers, and other office machines. Since many different makes and models of these machines are used in the Navy, you will probably get the chance to work on every kind. Instead of providing instruction on each, however, typical or representative machines will be chosen for discussion. It is assumed that there are no major differences between the typical machine and another of its kind. Already discussed in chapter 16 of Instrumentman 3/2, NavPers 10193-C, are the Burroughs Series P400 adding machine and the Class 200 Addressograph. This chapter will include a description of the various mechanisms and the nomenclature of those parts within the National Class 21 cash register, as well as procedures for disassembling, reassembling, and adjusting this typical cash register. Also included is a short section concerning the conversion of some Burroughs adding machines for use as cash registers. The last part of the chapter will provide procedures for adjusting the Burroughs Series P400 adding machine, whose mechanisms are described in Instrumentman 3/2.

NATIONAL CASH REGISTERS

The Model (Class) 21 National cash register is used in considerable numbers on naval ships; and for this reason, it is discussed as a representative type in this chapter. Figure 11-1 shows a Class 21 National cash register, with some of the nomenclature listed.

Illustrations of various mechanisms of the machine are shown when they are discussed. You can learn much about many of them at this time, however, by studying illustrations 11-2 through 11-11.

Reference is made to some of these illustrations during the discussion.

The Class 21 National cash register, also called the receipt printer, has one of transaction control keys in ROW 2 and five rows of AMOUNT keys. It is also constructed with clerks' keys in ROW 9, or with printing keys in ROWS 1 and 9.

This machine has ONE accumulating total and an itemizing feature. The items are accumulated on one set of counter pinions and then transferred to a storage total when the item counter is cleared. The storage counter and the item counter have a capacity of $9,999.99, each.

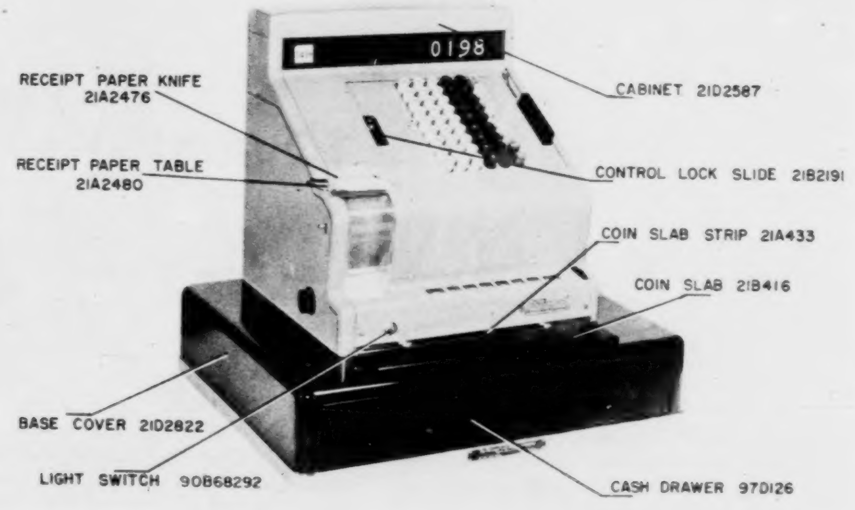
MECHANISMS AND PARTS

By necessity, the mechanisms in a cash register are complex. They are precision-made to function smoothly and accurately, and individually or collectively, in accordance with specific needs. Study the illustrations of mechanisms carefully as you follow the discussion of their operation.

Printer Selecting Plates

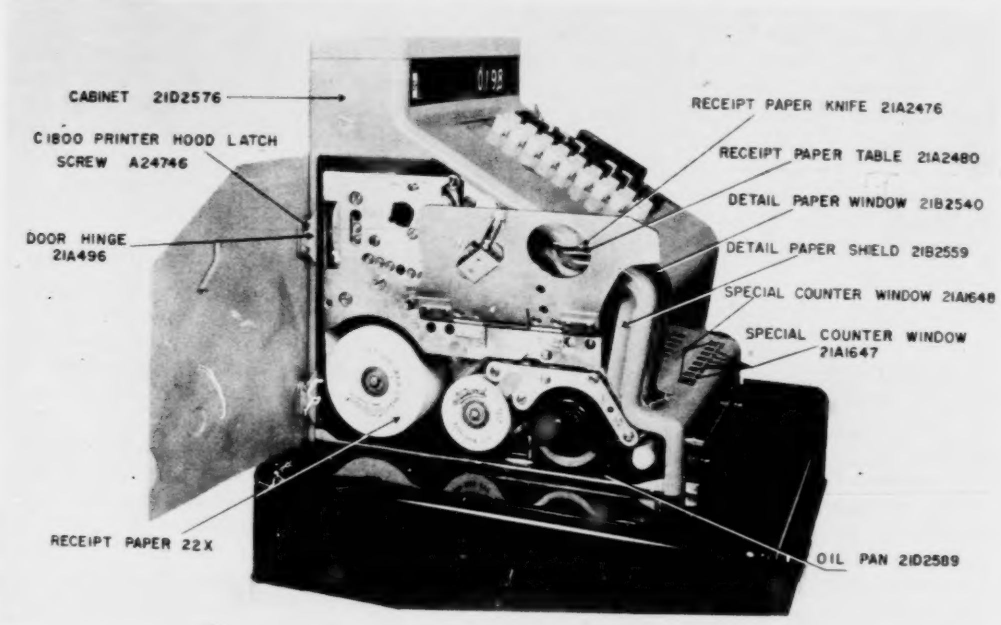
The feeding and printing of the receipt (slip of paper with printed record of sale) on the Class 21 National cash register is controlled by four selecting plates located back of the receipt supply roller hub. See figure 11-12. Plate 21A2487 is positioned by the link arm line in row 2 on the keyboard, and plate 21A2171 is positioned by the control lock slide (fig. 11-13). Torsion springs between printer selecting plates (fig. 11-12) 21A2164 and 21A2160 hold them against studs in plates 21A2487 and 21A2171. The positions of the last two plates determine the positions of plates 21A2164 and 21A2160.

Turn now to figure 11-14 and study the printer selecting plates in their operating positions. The lower sections of these plates have high, intermediate, and low spots which control the feeding and printing of the receipt.


0198
RECEIPT PAPER KNIFE 21A2476
RECEIPT PAPER TABLE 21A2480
CABINET 21D2587
CONTROL LOCK SLIDE 21B2191
COIN SLAB STRIP 21A433
COIN SLAB 21B416
BASE COVER 21D2822
LIGHT SWITCH 90B68292
CASH DRAWER 97D126

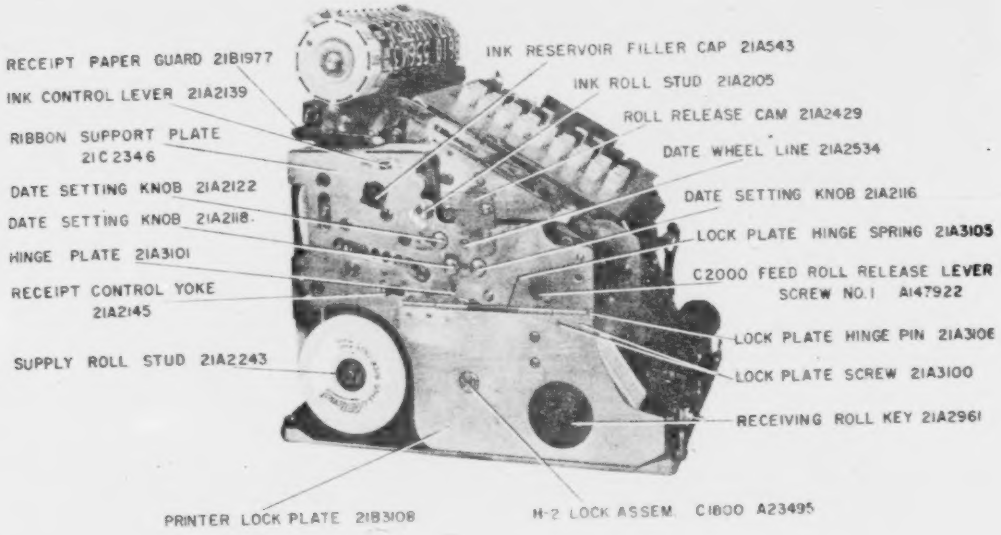
91.398X

Figure 11-1.—Class 21 National cash register.


0198
CABINET 21D2576
C1800 PRINTER HOOD LATCH SCREW A24746
DOOR HINGE 21A496
RECEIPT PAPER 22X
RECEIPT PAPER KNIFE 21A2476
RECEIPT PAPER TABLE 21A2480
DETAIL PAPER WINDOW 21B2540
DETAIL PAPER SHIELD 21B2559
SPECIAL COUNTER WINDOW 21A1648
SPECIAL COUNTER WINDOW 21A1647
OIL PAN 21D2589

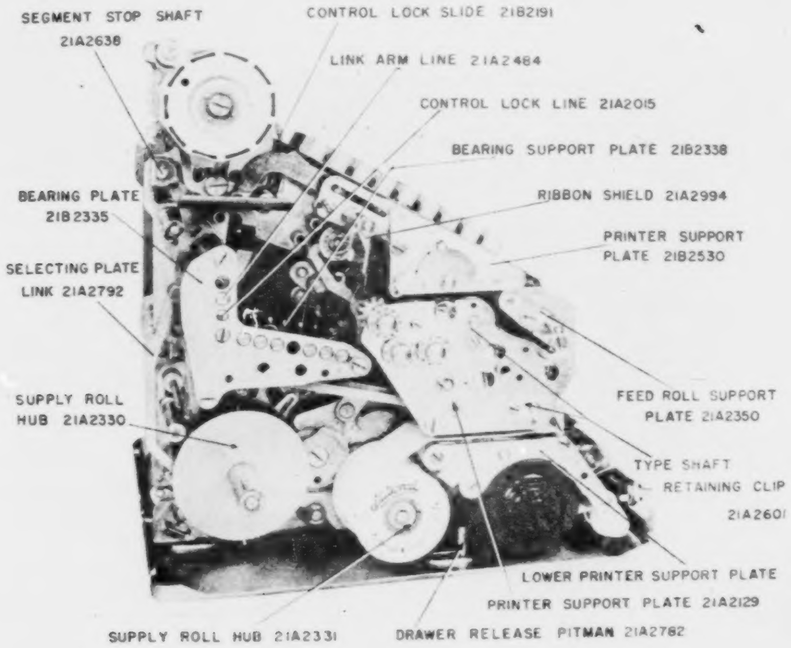
91.399X

Figure 11-2.—Nomenclature of a Class 21 National cash register.


RECEIPT PAPER GUARD 21B1977
INK CONTROL LEVER 21A2139
RIBBON SUPPORT PLATE 21C2346
DATE SETTING KNOB 21A2122
DATE SETTING KNOB 21A2118
HINGE PLATE 21A3101
RECEIPT CONTROL YOKE 21A2145
SUPPLY ROLL STUD 21A2243
INK RESERVOIR FILLER CAP 21A543
INK ROLL STUD 21A2105
ROLL RELEASE CAM 21A2429
DATE WHEEL LINE 21A2534
DATE SETTING KNOB 21A2116
LOCK PLATE HINGE SPRING 21A3105
C2000 FEED ROLL RELEASE LEVER SCREW NO.1 A147922
LOCK PLATE HINGE PIN 21A3106
LOCK PLATE SCREW 21A3100
RECEIVING ROLL KEY 21A2961
PRINTER LOCK PLATE 21B3108
H-2 LOCK ASSEM. C1800 A23495

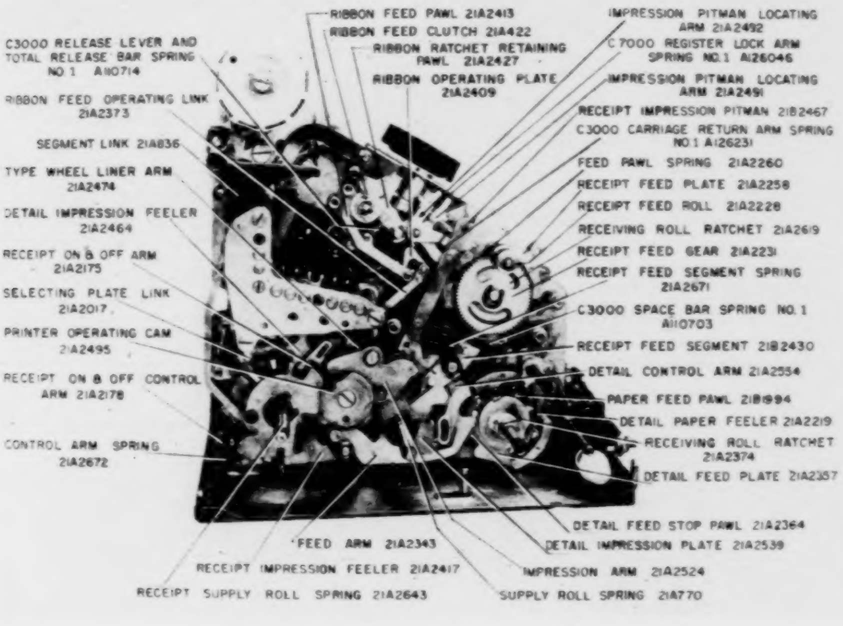
91.400X

Figure 11-3.—Nomenclature of a Class 21 National cash register—Continued.


SEGMENT STOP SHAFT 21A2638
CONTROL LOCK SLIDE 21B2191
LINK ARM LINE 21A2484
CONTROL LOCK LINE 21A2015
BEARING SUPPORT PLATE 21B2338
BEARING PLATE 21B2335
RIBBON SHIELD 21A2994
PRINTER SUPPORT PLATE 21B2530
SELECTING PLATE LINK 21A2792
SUPPLY ROLL HUB 21A2330
FEED ROLL SUPPORT PLATE 21A2350
TYPE SHAFT
RETAINING CLIP 21A2601
LOWER PRINTER SUPPORT PLATE
PRINTER SUPPORT PLATE 21A2129
SUPPLY ROLL HUB 21A2331
DRAWER RELEASE PITMAN 21A2782

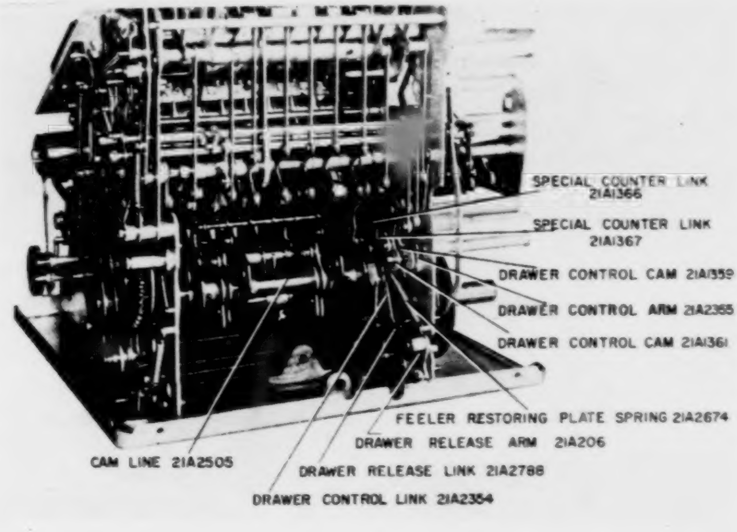
91.401X

Figure 11-4.—Nomenclature of a Class 21 National cash register—Continued.


RIBBON FEED PAWL 21A2413
RIBBON FEED CLUTCH 21A422
RIBBON RATCHET RETAINING PAWL 21A2427
RIBBON OPERATING PLATE 21A2409
IMPRESSION PITMAN LOCATING ARM 21A2492
C7000 REGISTER LOCK ARM SPRING NO.1 A126046
IMPRESSION PITMAN LOCATING ARM 21A2491
RECEIPT IMPRESSION PITMAN 21B2467
C3000 CARRIAGE RETURN ARM SPRING NO.1 A126231
FEED PAWL SPRING 21A2260
RECEIPT FEED PLATE 21A2258
RECEIPT FEED ROLL 21A2228
RECEIVING ROLL RATCHET 21A2619
RECEIPT FEED GEAR 21A2231
RECEIPT FEED SEGMENT SPRING 21A2671
C3000 SPACE BAR SPRING NO.1 A110703
RECEIPT FEED SEGMENT 21B2430
DETAIL CONTROL ARM 21A2554
PAPER FEED PAWL 21B1994
DETAIL PAPER FEELER 21A2219
RECEIVING ROLL RATCHET 21A2374
DETAIL FEED PLATE 21A2357
C3000 RELEASE LEVER AND TOTAL RELEASE BAR SPRING NO.1 A110714
RIBBON FEED OPERATING LINK 21A2373
SEGMENT LINK 21A836
TYPE WHEEL LINER ARM 21A2474
DETAIL IMPRESSION FEELER 21A2464
RECEIPT ON & OFF ARM 21A2175
SELECTING PLATE LINK 21A2017
PRINTER OPERATING CAM 21A2495
RECEIPT ON & OFF CONTROL ARM 21A2178
CONTROL ARM SPRING 21A2672
DETAIL FEED STOP PAWL 21A2364
DETAIL IMPRESSION PLATE 21A2539
FEED ARM 21A2343
RECEIPT IMPRESSION FEELER 21A2417
IMPRESSION ARM 21A2524
RECEIPT SUPPLY ROLL SPRING 21A2643
SUPPLY ROLL SPRING 21A770

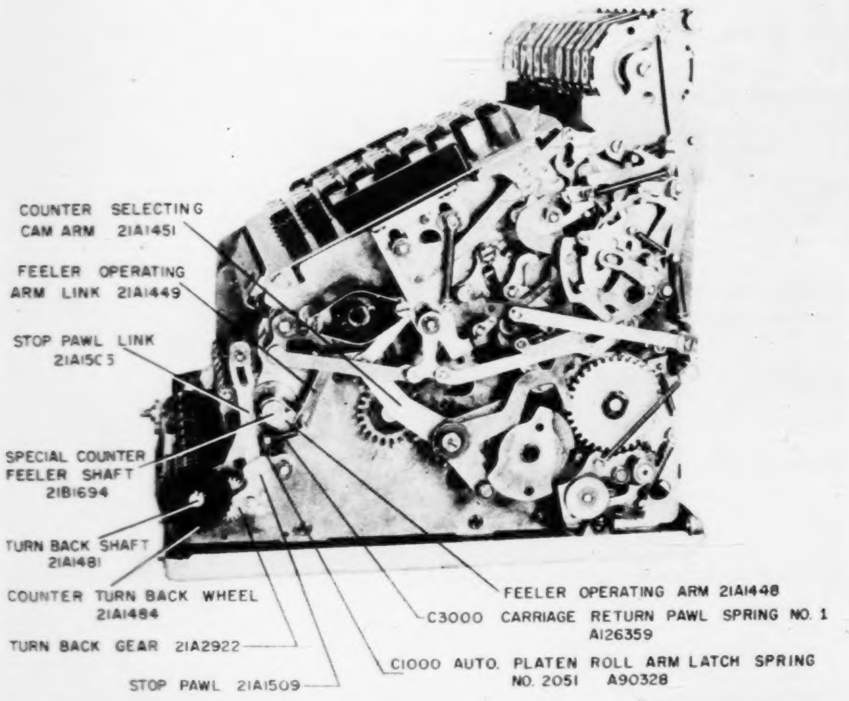
91.402X

Figure 11-5. — Nomenclature of a Class 21 National cash register — Continued.


SPECIAL COUNTER LINK 21A1366
SPECIAL COUNTER LINK 21A1367
DRAWER CONTROL CAM 21A1359
DRAWER CONTROL ARM 21A2355
DRAWER CONTROL CAM 21A1361
FEELER RESTORING PLATE SPRING 21A2674
DRAWER RELEASE ARM 21A206
CAM LINE 21A2505
DRAWER RELEASE LINK 21A2788
DRAWER CONTROL LINK 21A2354

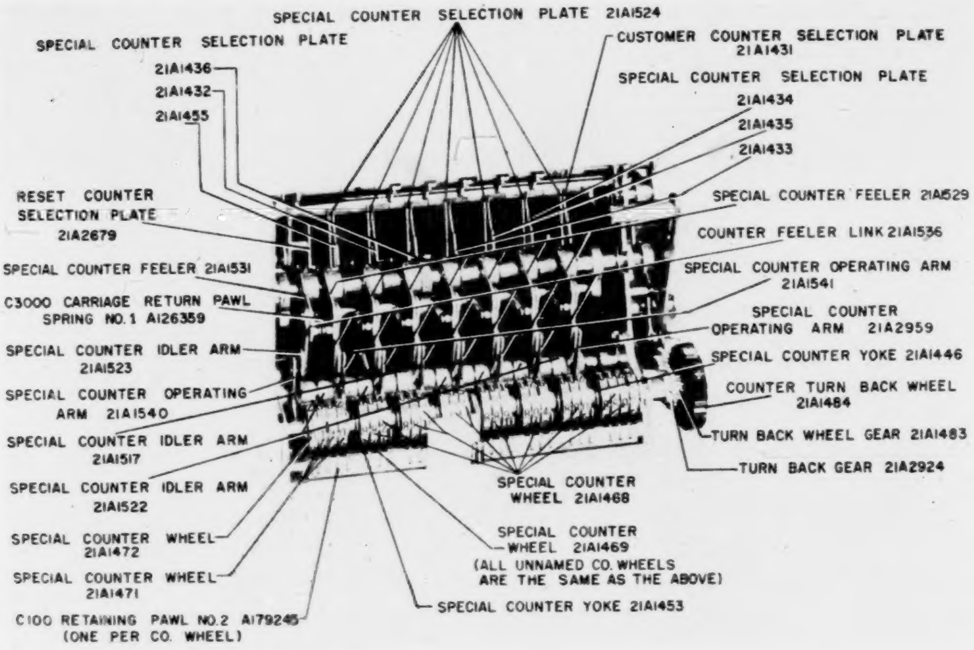
91.403X

Figure 11-6. — Nomenclature of a Class 21 National cash register — Continued.


COUNTER SELECTING CAM ARM 21A1451
FEELER OPERATING ARM LINK 21A1449
STOP PAWL LINK 21A15C5
SPECIAL COUNTER FEELER SHAFT 21B1694
TURN BACK SHAFT 21A1481
COUNTER TURN BACK WHEEL 21A1484
TURN BACK GEAR 21A2922
STOP PAWL 21A1509
FEELER OPERATING ARM 21A1448
C3000 CARRIAGE RETURN PAWL SPRING NO. 1 A126359
C1000 AUTO. PLATEN ROLL ARM LATCH SPRING NO. 2051 A90328

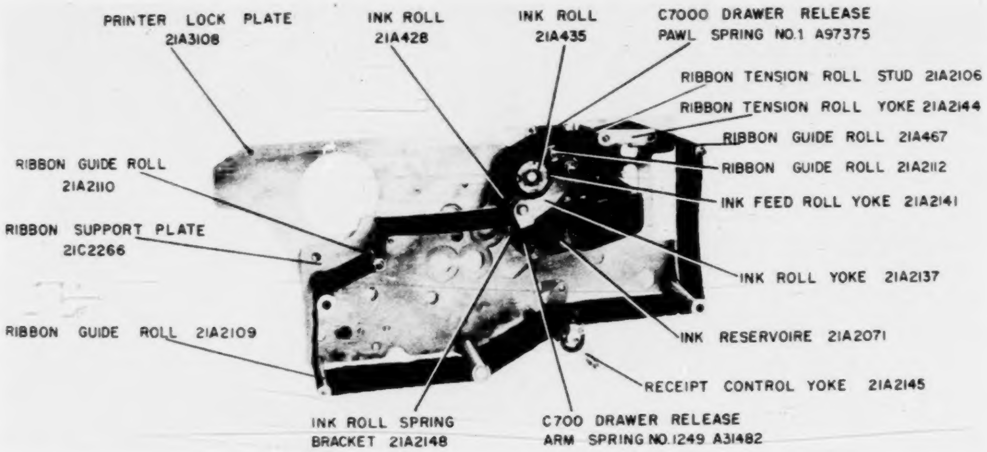
91.404X

Figure 11-7.—Nomenclature of a Class 21 National cash register—Continued.


SPECIAL COUNTER SELECTION PLATE 21A1524
SPECIAL COUNTER SELECTION PLATE
21A1436
21A1432
21A1455
CUSTOMER COUNTER SELECTION PLATE 21A1431
SPECIAL COUNTER SELECTION PLATE
21A1434
21A1435
21A1433
RESET COUNTER SELECTION PLATE 21A2679
SPECIAL COUNTER FEELER 21A1529
COUNTER FEELER LINK 21A1536
SPECIAL COUNTER FEELER 21A1531
SPECIAL COUNTER OPERATING ARM 21A1541
C3000 CARRIAGE RETURN PAWL SPRING NO.1 A126359
SPECIAL COUNTER OPERATING ARM 21A2959
SPECIAL COUNTER IDLER ARM 21A1523
SPECIAL COUNTER YOKE 21A1446
SPECIAL COUNTER OPERATING ARM 21A1540
COUNTER TURN BACK WHEEL 21A1484
SPECIAL COUNTER IDLER ARM 21A1517
TURN BACK WHEEL GEAR 21A1483
TURN BACK GEAR 21A2924
SPECIAL COUNTER IDLER ARM 21A1522
SPECIAL COUNTER WHEEL 21A1468
SPECIAL COUNTER WHEEL 21A1472
SPECIAL COUNTER WHEEL 21A1469
(ALL UNNAMED CO. WHEELS ARE THE SAME AS THE ABOVE)
SPECIAL COUNTER WHEEL 21A1471
SPECIAL COUNTER YOKE 21A1453
C100 RETAINING PAWL NO.2 A179245 (ONE PER CO. WHEEL)

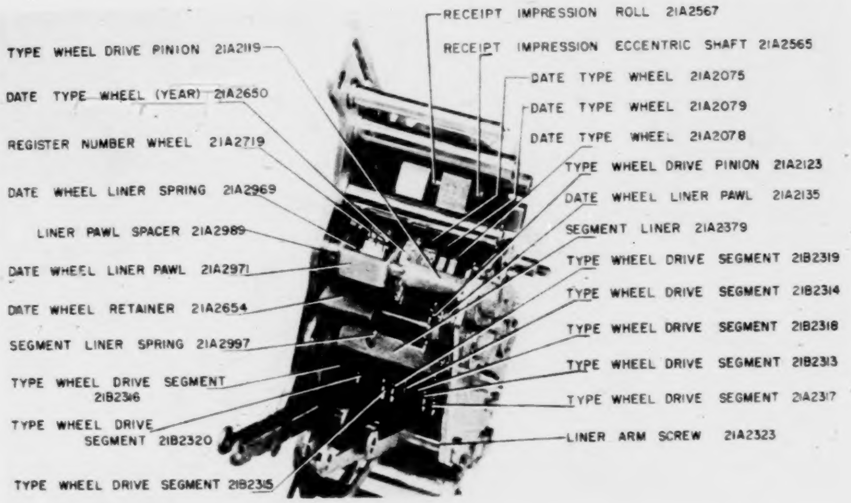
91.405X

Figure 11-8.—Nomenclature of a Class 21 National cash register—Continued.


PRINTER LOCK PLATE 21A3108
INK ROLL 21A428
INK ROLL 21A435
C7000 DRAWER RELEASE PAWL SPRING NO.1 A97375
RIBBON TENSION ROLL STUD 21A2106
RIBBON TENSION ROLL YOKE 21A2144
RIBBON GUIDE ROLL 21A467
RIBBON GUIDE ROLL 21A2110
RIBBON GUIDE ROLL 21A2112
INK FEED ROLL YOKE 21A2141
RIBBON SUPPORT PLATE 21C2266
INK ROLL YOKE 21A2137
RIBBON GUIDE ROLL 21A2109
INK RESERVOIRE 21A2071
RECEIPT CONTROL YOKE 21A2145
INK ROLL SPRING BRACKET 21A2148
C700 DRAWER RELEASE ARM SPRING NO.1249 A31482

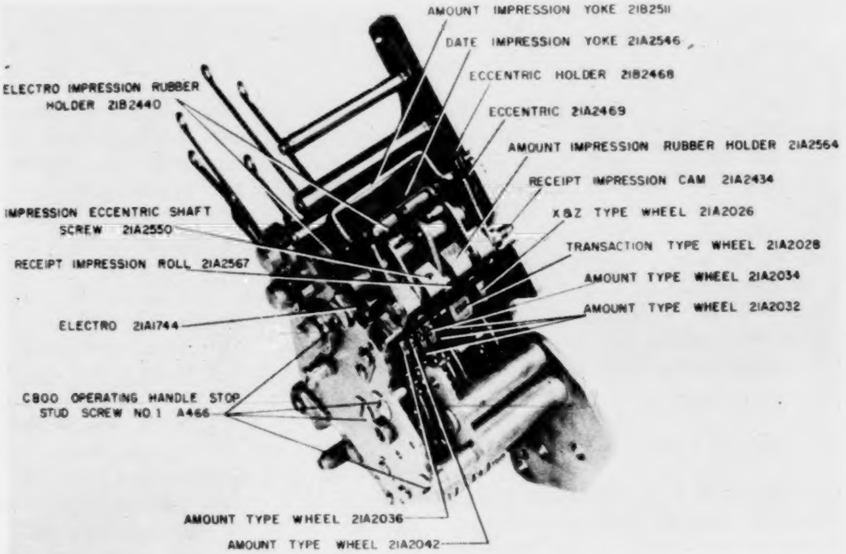
91.406X

Figure 11-9.—Nomenclature of a Class 21 National cash register—Continued.


RECEIPT IMPRESSION ROLL 21A2567
TYPE WHEEL DRIVE PINION 21A2119
RECEIPT IMPRESSION ECCENTRIC SHAFT 21A2565
DATE TYPE WHEEL 21A2075
DATE TYPE WHEEL (YEAR) 21A2650
DATE TYPE WHEEL 21A2079
REGISTER NUMBER WHEEL 21A2719
DATE TYPE WHEEL 21A2078
TYPE WHEEL DRIVE PINION 21A2123
DATE WHEEL LINER SPRING 21A2969
DATE WHEEL LINER PAWL 21A2135
LINER PAWL SPACER 21A2989
SEGMENT LINER 21A2379
DATE WHEEL LINER PAWL 21A2971
TYPE WHEEL DRIVE SEGMENT 21B2319
DATE WHEEL RETAINER 21A2654
TYPE WHEEL DRIVE SEGMENT 21B2314
SEGMENT LINER SPRING 21A2997
TYPE WHEEL DRIVE SEGMENT 21B2318
TYPE WHEEL DRIVE SEGMENT 21B2316
TYPE WHEEL DRIVE SEGMENT 21B2313
TYPE WHEEL DRIVE SEGMENT 21A2317
TYPE WHEEL DRIVE SEGMENT 21B2320
LINER ARM SCREW 21A2323
TYPE WHEEL DRIVE SEGMENT 21B2315

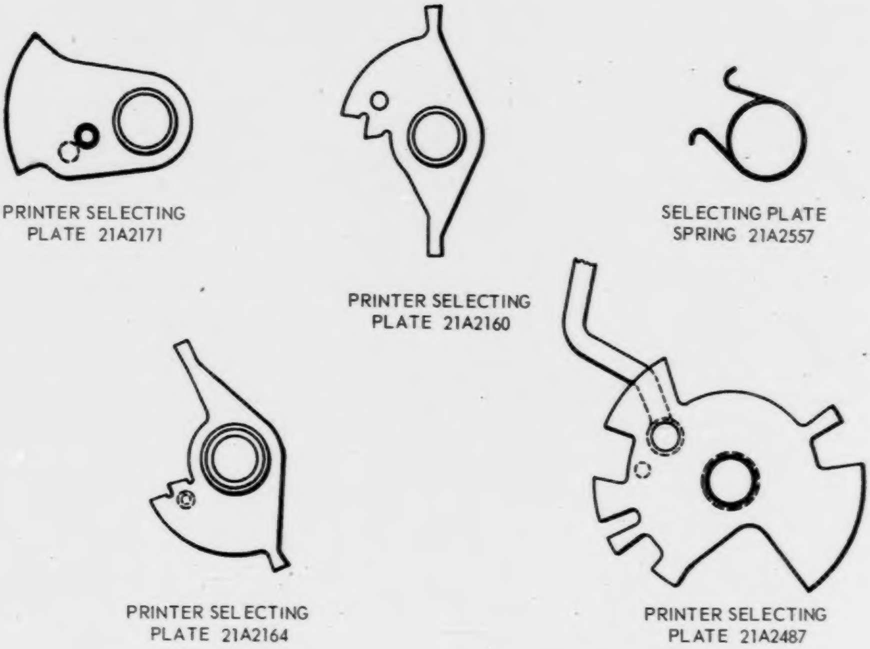
91.407X

Figure 11-10.—Nomenclature of a Class 21 National cash register—Continued.


AMOUNT IMPRESSION YOKE 21B2511
DATE IMPRESSION YOKE 21A2546
ECCENTRIC HOLDER 21B2468
ELECTRO IMPRESSION RUBBER HOLDER 21B2440
ECCENTRIC 21A2469
AMOUNT IMPRESSION RUBBER HOLDER 21A2564
RECEIPT IMPRESSION CAM 21A2434
IMPRESSION ECCENTRIC SHAFT SCREW 21A2550
X&Z TYPE WHEEL 21A2026
TRANSACTION TYPE WHEEL 21A2028
RECEIPT IMPRESSION ROLL 21A2567
AMOUNT TYPE WHEEL 21A2034
AMOUNT TYPE WHEEL 21A2032
ELECTRO 21A1744
C800 OPERATING HANDLE STOP STUD SCREW NO.1 A466
AMOUNT TYPE WHEEL 21A2036
AMOUNT TYPE WHEEL 21A2042

91.408X

Figure 11-11.—Nomenclature of a Class 21 National cash register—Continued.


PRINTER SELECTING PLATE 21A2171
PRINTER SELECTING PLATE 21A2160
SELECTING PLATE SPRING 21A2557
PRINTER SELECTING PLATE 21A2164
PRINTER SELECTING PLATE 21A2487

91.409X

Figure 11-12. — Printer selecting plates.

The high spots result in NO feeding and NO printing; the intermediate spots give the amount of printing ONLY and SHORT feeding; and the low spots give the AMOUNT and DATE printing and LONG feeding.

The upper sections of the selecting plates have high and low spots which control the feeding and printing of the detail strip (paper which remains in the machine for auditing purposes). The high spots give NO feeding and NO printing, and the low spots cause the detail strip to feed and receive print.

On and off Receipt Control Yoke

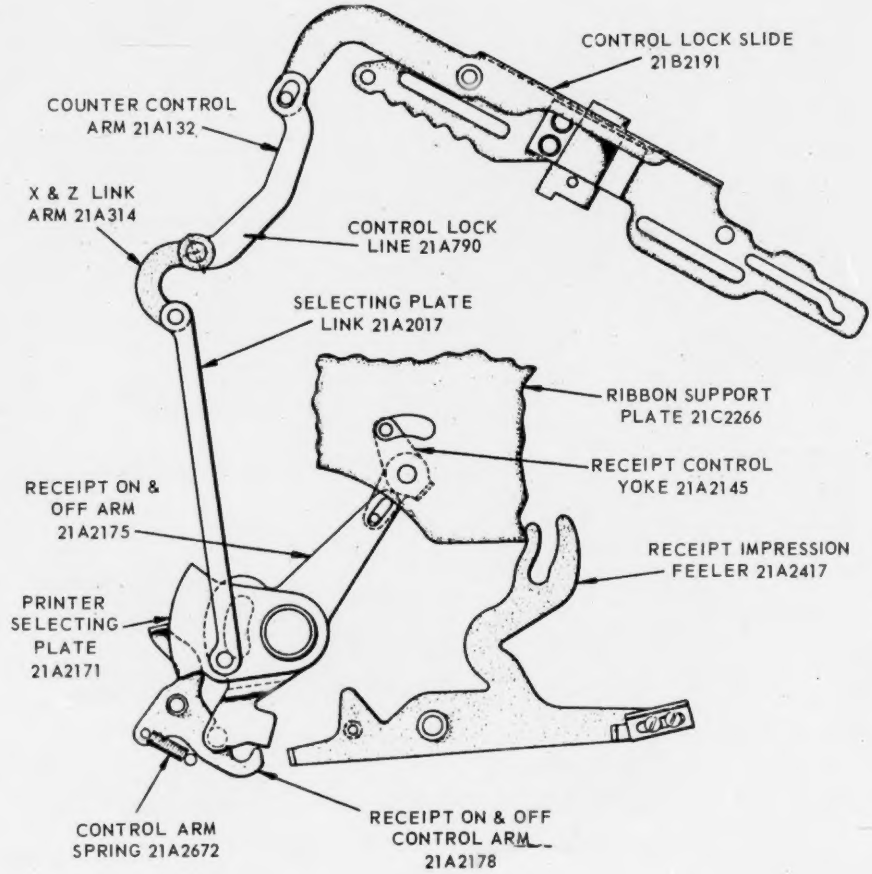
If the control lock slide (fig. 11-13) is in any position except RESET, a high spot on selecting plate 21A2171 gets in the path of the receipt control yoke. Illustration 11-13 shows the control lock slide in the REGISTERING position.

When the receipt control yoke is in the OFF position, the lower portion of the receipt ON-and-OFF arm is over the receipt impression feeler (illustrated). This portion of the receipt ON-and-OFF arm corresponds to a high spot on the printer selecting plates and disables the feeding and printing of the receipt.

When the receipt control yoke is moved from one position to the other, the stud in the lower end of the receipt ON-and-OFF arm forces the front end of the receipt ON-and-OFF control arm down and oscillates the second control arm from the top to the front of the machine to build up tension in the control spring. The upper end of the control arm has a TURNED-OVER part which enters a low spot in selecting plate 21A-2171. After the stud in the lower end of the receipt ON-and-OFF arm passes over the receipt ON-and-OFF control arm, the control arm spring (illustrated) pulls the control arm from the top to the back of the machine and the upper end of the control arm moves out of the LOW spot in the selecting plate.

Feeler Restoring Plate

The feeler restoring plate (fig. 11-15) is located back of the printer selecting plates, next to the left side frame. When the handle is


CONTROL LOCK SLIDE
21B2191
COUNTER CONTROL
ARM 21A132
X & Z LINK
ARM 21A314
CONTROL LOCK
LINE 21A790
SELECTING PLATE
LINK 21A2017
RIBBON SUPPORT
PLATE 21C2266
RECEIPT CONTROL
YOKE 21A2145
RECEIPT ON &
OFF ARM
21A2175
RECEIPT IMPRESSION
FEELER 21A2417
PRINTER
SELECTING
PLATE
21A2171
CONTROL ARM
SPRING 21A2672
RECEIPT ON & OFF
CONTROL ARM
21A2178

91.410X

Figure 11-13. — ON-and-OFF receipt control yoke.

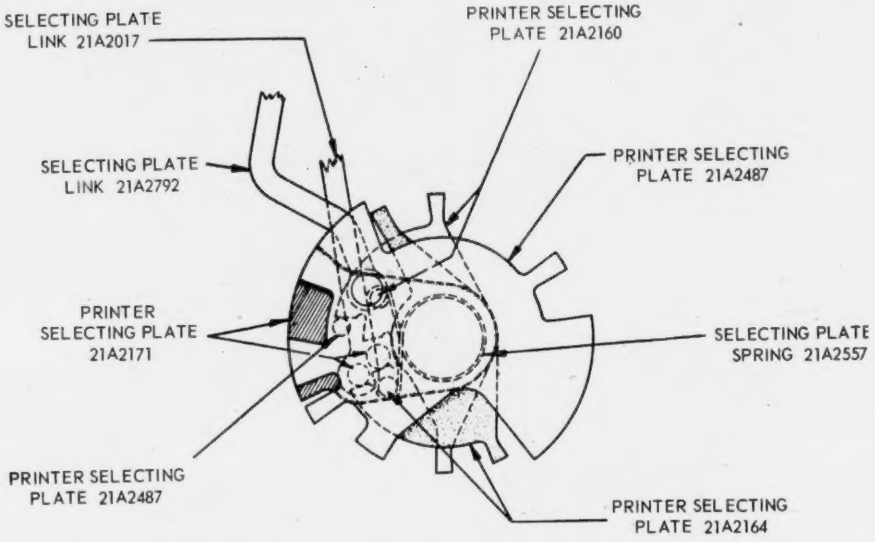

SELECTING PLATE LINK 21A2017
PRINTER SELECTING PLATE 21A2160
SELECTING PLATE LINK 21A2792
PRINTER SELECTING PLATE 21A2487
PRINTER SELECTING PLATE 21A2171
SELECTING PLATE SPRING 21A2557
PRINTER SELECTING PLATE 21A2487
PRINTER SELECTING PLATE 21A2164

Figure 11-14.—Printer selecting plates in their operating positions. 91.411X

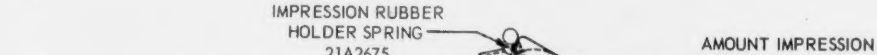
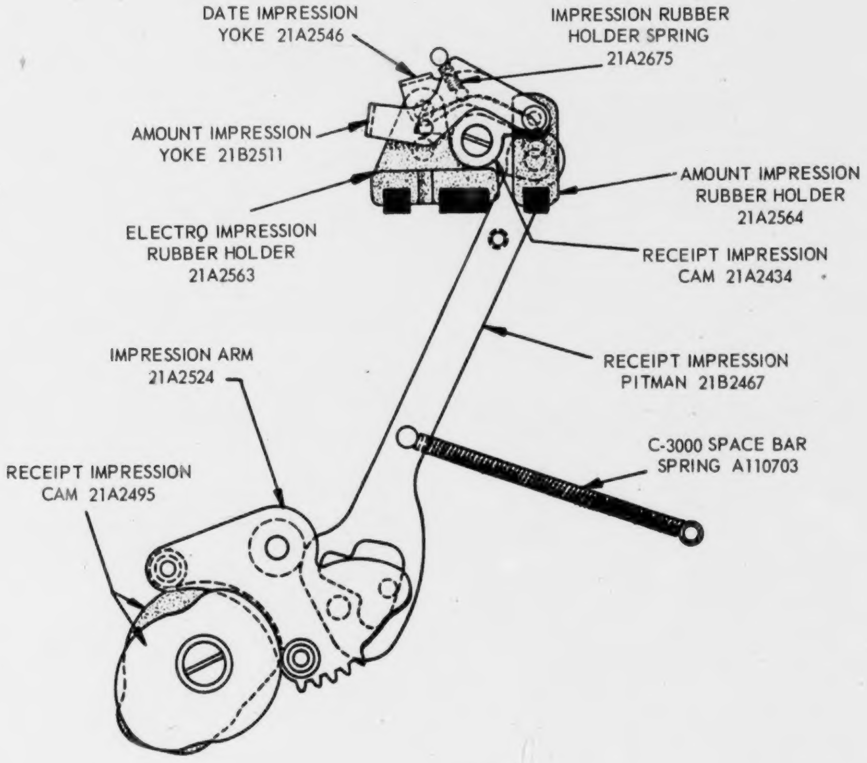

IMPRESSION RUBBER HOLDER SPRING 21A2675
AMOUNT IMPRESSION RUBBER HOLDER 21A2564
DATE IMPRESSION YOKE 21A2546
AMOUNT IMPRESSION YOKE 21B2511
RECEIPT IMPRESSION CAM 21A2434
ELECTRO IMPRESSION RUBBER HOLDER 21A2563
RECEIPT IMPRESSION PITMAN 21B2467
SINGLE ITEM-TOTAL
C-3000 SPACE BAR SPRING A110703
PRINTER SELECTING PLATE 21A2487
PAPER FEED CAM 21A2495
MULTIPLE ITEM
NEUTRAL
RECEIPT IMPRESSION FEELER 21A2417
RECEIPT FEED ADJUSTING PLATE 21A2262
RECEIPT FEED ADJUSTING PLATE 21A2990
FEELER RESTORING PLATE SPRING 21A2674
FEELER RESTORING PLATE 21A2213

Figure 11-15.—Feeler restoring plate and attached parts and mechanisms. 91.412X


DATE IMPRESSION YOKE 21A2546
IMPRESSION RUBBER HOLDER SPRING 21A2675
AMOUNT IMPRESSION YOKE 21B2511
AMOUNT IMPRESSION RUBBER HOLDER 21A2564
ELECTRO IMPRESSION RUBBER HOLDER 21A2563
RECEIPT IMPRESSION CAM 21A2434
IMPRESSION ARM 21A2524
RECEIPT IMPRESSION PITMAN 21B2467
C-3000 SPACE BAR SPRING A110703
RECEIPT IMPRESSION CAM 21A2495

91.413X

Figure 11-16. — Receipt impression pitman and connected parts and mechanisms.

turned 1/2 turn (180°) from its normal rest position (HOME), the restoring plate is held with the top up and to the FRONT of the machine by three rollers on the inside printer operating cam. In this position, the restoring plate holds both impression feelers clear of the selecting plates while they are being positioned.

At the completion of a 1/2 turn of the handle (crank), the rollers on the printer operating cam move away from the feeler restoring plate and the feeler restoring plate spring pulls the restoring plate to the BACK of the machine, thereby allowing the feelers to move in and FEEL for HIGH or LOW spots on the selecting plates.

Receipt Impression Pitman

The upper end of the receipt impression pitman (fig. 11-15) swings on a stud in the receipt impression cam, and it has a spring which pulls its lower end toward the front of the machine. A stud in the front end of the impression arm (fig. 11-16) works in an opening in the lower end of the pitman. As illustrated in figure 11-15 the opening in the pitman has a NEUTRAL portion and two WORKING portions (single and multiple). In the rest (HOME) position, the stud in the impression arm is in the center of the neutral portion.

The upper extension of the receipt impression feeler (fig. 11-15) fits over a stud in the pitman; and if a high spot on one of the printer selecting plates is positioned over the feeler during the operation, the neutral portion of the pitman remains over the stud in the impression arm.

When in the HOME position, the impression arm (fig. 11-16) is on the intermediate part of the printer operating cam (fig. 11-15, & 21A2495 figs. 11-16 & 11-17). The first movement of the arm is from TOP to BACK when the handle is

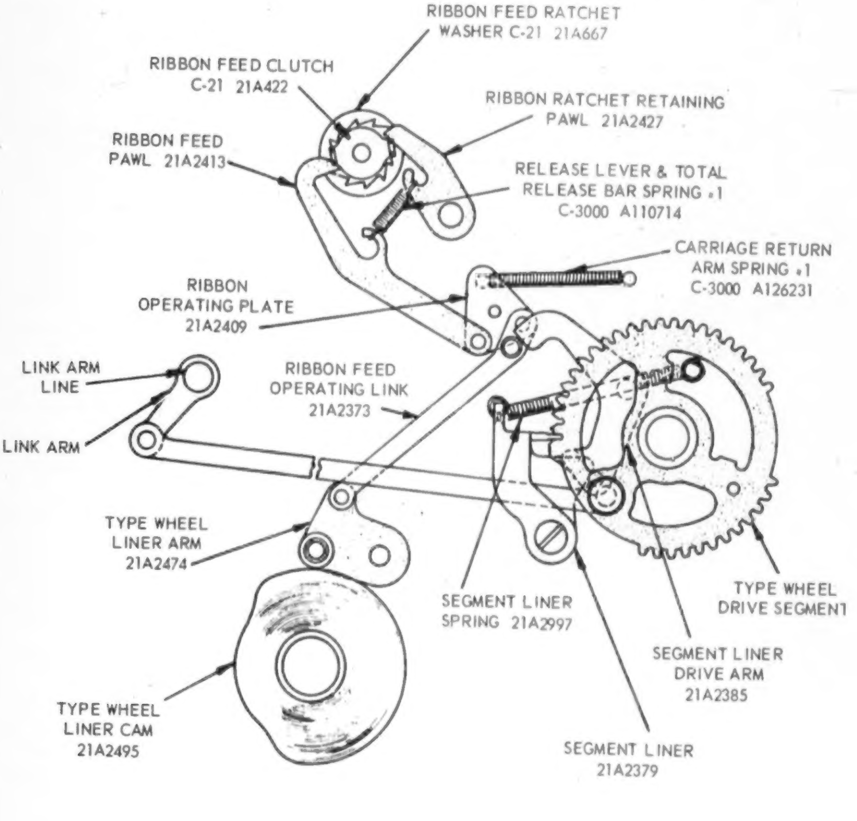

RIBBON FEED RATCHET WASHER C-21 21A667
RIBBON FEED CLUTCH C-21 21A422
RIBBON RATCHET RETAINING PAWL 21A2427
RIBBON FEED PAWL 21A2413
RELEASE LEVER & TOTAL RELEASE BAR SPRING •1 C-3000 A110714
CARRIAGE RETURN ARM SPRING •1 C-3000 A126231
RIBBON OPERATING PLATE 21A2409
LINK ARM LINE
RIBBON FEED OPERATING LINK 21A2373
LINK ARM
TYPE WHEEL LINER ARM 21A2474
SEGMENT LINER SPRING 21A2997
TYPE WHEEL DRIVE SEGMENT
SEGMENT LINER DRIVE ARM 21A2385
TYPE WHEEL LINER CAM 21A2495
SEGMENT LINER 21A2379

Figure 11-17. — Type wheel aligning and ribbon feeding mechanism. 91.414X

turned 3/4 the distance around. Upon completion of a FULL turn of the handle, the arm returns to the intermediate part of the cam. At the completion of one and 3/8 turns of the handle, the arm oscillates TOP to FRONT; and with the stud in the impression arm in the neutral portion of the opening in the pitman, the pitman does NOT move and NO printing occurs on the receipt.

If the intermediate spots on the selecting plates are positioned over the receipt impression feeler (fig. 11-15), the receipt impression pitman moves to the FRONT and places the first WORKING portion of the opening under the stud in the impression arm. This portion of the opening is so cut that when the impression arm oscillates TOP to BACK as the handle is turned 3/4 the distance around, the stud does NOT contact the pitman; but when the arm oscillates TOP to FRONT after the handle is turned one and 3/8 turns, the stud DOES contact the pitman and carry it DOWN to print amounts on the receipt.

When LOW spots on the selecting plates are positioned over the receipt impression feeler, the receipt impression pitman moves to the FRONT and places the SECOND working portion of the opening in the pitman over the stud in the impression arm. This position of the opening is so cut that the stud in the impression arm contacts the pitman when the handle is turned 3/4 the distance around and forces it UP to print the date and electro (name plate of firm, etc.) on the receipt. If the handle is turned one and 3/8 turns, the stud carries the pitman down to print the amounts on the receipt.

Studs in the FRONT and BACK printer support plates (fig. 11-4) hold the amount inpression yoke (fig. 11-16) on studs. The amount impression rubber holder is assembled to the FRONT of this yoke. The date impression yoke is attached to both the amount and the electro impression rubber holders and the impression rubber holder springs. An upward pull on the date impression yoke holds both impression rubber holders UP off the type in the HOME position.

The receipt impression cam swings on a stud in the back printer support plate, and it has extensions to the FRONT and to the BACK over the amount and the electro impression rubber holders.

When the receipt impression pitman (fig. 11-16) moves UP, it oscillates the impression cam from the top to the back of the machine, and the back extension of the cam then forces the electro impression rubber holder DOWN against the type to print.

When the receipt impression pitman is moved DOWN below the HOME position, the receipt impression cam oscillates TOP to FRONT and carries the amount impression rubber holder DOWN to print the amounts on the receipt.

Printer Operating Cam

The printer operating cam (figs. 11-5 & 11-16) is a cluster of four cams on the left end of the printer cam line (fig. 11-6). The two OUTSIDE cams operate the detail and receipt impression mechanism (receipt impression cam), illustrated in figure 11-16. The third cam from the outside operates the type wheel liner arm (fig. 11-17). The type wheel liner arm operates both the liner and the ribbon feed mechanism (type wheel liner cam).

Three rollers on the side of the inside cam of the cluster operate the feeler restoring plate (fig. 11-15). The surface of the cam operates the paper feeding mechanism (fig. 11-18) for BOTH the detail and the receipt paper (paper feeding cam).

Paper Feeding Mechanism

The receipt impression feeler (fig. 11-15) also controls the feeding of the receipt paper. The receipt feed adjusting plate (21A2262, fig. 11-18) is located slightly LOWER on the feeler than feed adjusting plate 21A2990. When a high spot on one of the selecting plates is positioned over the receipt impression feeler, adjusting plate 21A2262 is in the PATH of receipt feeding segment 21B2430 (fig. 11-18) and does NOT let the segment COCK the receipt feeding mechanism; so the receipt paper does NOT feed.

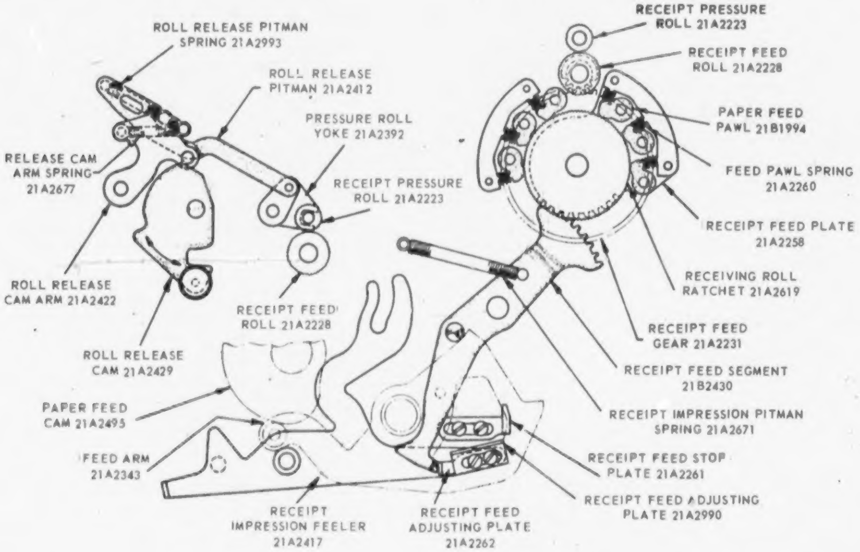
When INTERMEDIATE spots on the printer selecting plates are positioned over the receipt impression feeler (fig. 11-15), the front extension of the feeler moves DOWN slightly and the receipt feeding adjusting plate (fig. 11-18) is moved DOWN and OUT of the path of the receipt feeding segment. Receipt feeding adjusting plate 21A2990 is secured slightly HIGHER and a little to the FRONT of adjusting plate 21A2262; and when the receipt impression feeler is on an intermediate spot on the selecting plates, adjusting plate 21A2990 is IN THE PATH of the receipt feeding segment. When in this position, plate 21A2990 allows the receipt feeding segment to move TOP to BACK far enough to cock the receipt feeding mechanism sufficiently to feed the paper 1/4 inch.

When LOW spots on the selecting plates are positioned OVER the impression feeler, the front extension of the feeler moves DOWN and carries BOTH adjusting plates OUT of the path of the receipt feeding segment. The segment then moves BOTTOM to FRONT until it is stopped by the receipt feeding stop plate (21A-2261) screwed to the left side frame. This movement COCKS the receipt feeding mechanism for LONG feeding.

Type Wheel and Ribbon Feeding Mechanism

Movement to position the type wheels (fig. 11-18) is provided by the link arm lines (fig. 11-17). Differential links swing on studs in the link arms pinned to the link arm lines outside the left side frame. The front end of the differential links swings on studs in the type wheel drive segment (fig. 11-17). This mechanism positions the drive segments, which (in mesh with the type wheels) then position the type wheels.

One complete turn of the handle fully positions the type wheels. Just after the completion of one turn of the handle, the LOW part of the printer operating cam (fig. 11-16) comes UNDER the roller and stud on the type wheel liner arm (21A2474, fig. 11-17) and the segment liner spring pulls the segment liner (fig. 11-17) from the top to the front of the machine and into the teeth of the type wheel drive segments, thereby aligning the segments and type wheels.


ROLL RELEASE PITMAN SPRING 21A2993
ROLL RELEASE PITMAN 21A2412
PRESSURE ROLL YOKE 21A2392
RELEASE CAM ARM SPRING 21A2677
RECEIPT PRESSURE ROLL 21A2223
ROLL RELEASE CAM ARM 21A2422
RECEIPT FEED ROLL 21A2228
ROLL RELEASE CAM 21A2429
PAPER FEED CAM 21A2495
FEED ARM 21A2343
RECEIPT IMPRESSION FEELER 21A2417
RECEIPT FEED ADJUSTING PLATE 21A2262
RECEIPT PRESSURE ROLL 21A2223
RECEIPT FEED ROLL 21A2228
PAPER FEED PAWL 21B1994
FEED PAWL SPRING 21A2260
RECEIPT FEED PLATE 21A2258
RECEIVING ROLL RATCHET 21A2619
RECEIPT FEED GEAR 21A2231
RECEIPT FEED SEGMENT 21B2430
RECEIPT IMPRESSION PITMAN SPRING 21A2671
RECEIPT FEED STOP PLATE 21A2261
RECEIPT FEED ADJUSTING PLATE 21A2990

91.415X

Figure 11-18.—Paper feeding mechanism.

As the segment liner moves into the teeth of the segments, it contacts the segment liner drive arm and moves it TOP to BACK. The segment liner drive arm (fig. 11-17) swings on a stud in the back printer support plate, and the top of the arm moves to the back and contacts a stud in the ribbon feeding operating link which extends through an opening in the back printer support plate. The link is then forced to the BACK of the machine to cause the roller and stud on the type wheel liner arm to follow the surface of the printer operating cam.

The upper end of the ribbon feeding operating link (fig. 11-17) is attached to the ribbon operating plate; and as the link moves to the back, the plate is turned TOP to FRONT. The lower end of the ribbon feeding pawl (fig. 11-17) is attached to the ribbon operating plate, and the upper end of the pawl is held against the ratchet of the ribbon feeding clutch by spring tension. As the operating plate turns TOP to FRONT, it carries the feeding pawl up and cocks the ribbon feeding mechanism. The ribbon ratchet retaining pawl (fig. 11-17) keeps the ribbon feeding clutch from turning when the pawl moves over the ratchet.

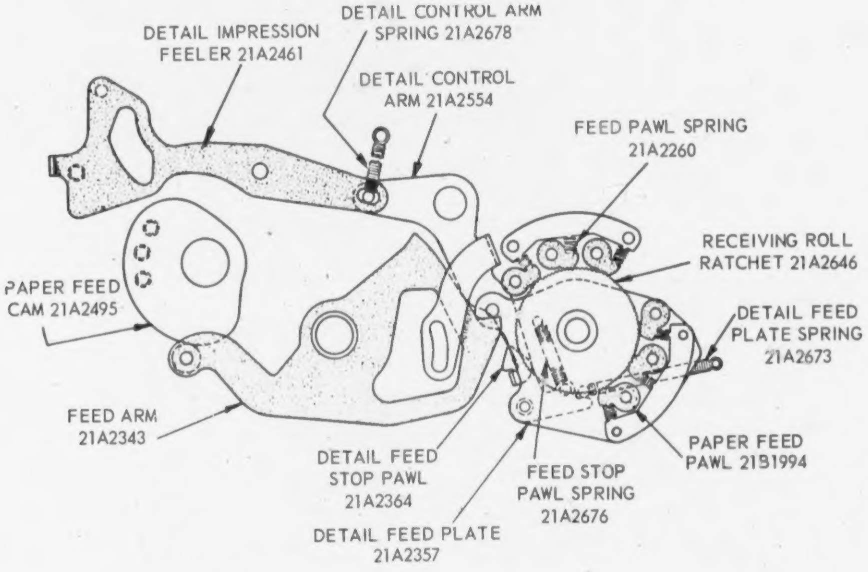
Just before the handle completes one and 3/4 turns, the HIGH part of the printer operating cam (21A2405, fig. 11-16) comes UNDER the roller and stud in the type wheel liner arm and forces the arm UP. The ribbon feeding operating link then moves UP and to the FRONT of the machine. The stud in the upper part of the link contacts the segment liner drive arm and moves it TOP to FRONT. The lower part of the segment liner drive arm then contacts the segment liner and carries it out of the teeth of the segments.

The ribbon feeding operating link also turns the ribbon operating plate TOP to BACK. The ribbon feeding pawl is then moved DOWN to turn the ribbon feeding clutch TOP to BACK. The ribbon feeding clutch continues the action by turning the ink roller (fig. 11-9) TOP to BACK to feed the ribbon ONE position.

Multiple-item Operations

From the HOME position to a 1/2 turn of the handle, the rollers on the printer operating cam hold the feeler restoring plate (fig. 11-15) TOP to FRONT. In this position, the restoring plate holds the impression feelers clear of the HIGH spots on the selecting plates while they are being positioned.

A 3/8 turn of the handle fully positions the selecting plates; at the completion of 1/2 turn


DETAIL IMPRESSION FEELER 21A2461
DETAIL CONTROL ARM SPRING 21A2678
DETAIL CONTROL ARM 21A2554
FEED PAWL SPRING 21A2260
RECEIVING ROLL RATCHET 21A2646
PAPER FEED CAM 21A2495
DETAIL FEED PLATE SPRING 21A2673
FEED ARM 21A2343
PAPER FEED PAWL 21B1994
DETAIL FEED STOP PAWL 21A2364
FEED STOP PAWL SPRING 21A2676
DETAIL FEED PLATE 21A2357

91.416X

Figure 11-19.—Detail strip printing and feeding mechanism.

of the handle, the rollers on the printer operating cam move AWAY from the feeler restoring plate and this plate's spring then pulls the plate TOP to BACK.

The upper extension of the receipt impression feeler (fig. 11-18) yokes over a stud in the receipt impression pitman, and a spring pulls this pitman to the front of the machine to cause the feeler to move UP in the BACK until it contacts an intermediate spot on the printer selecting plates.

The receipt impression pitman then moves to the FRONT and places the first working portion of the opening in it over the stud in the impression arm (fig. 11-16) to set up a condition for the amounts ONLY to be printed on the receipt paper.

The front of the receipt impression feeler (fig. 11-18) moves DOWN and positions adjusting plate 21A2990 in the path of the receipt feeding segment, thereby setting up a condition for SHORT feeding of the receipt paper.

in the HOME position, the high part of the printer operating cam is over the roller and stud in the back part of the feed arm (fig. 11-19) and thus holds it down. The front of the feed arm is against a stud in the receipt feeding segment (fig. 11-18) and thus holds the segment TOP to FRONT.

Just after a 1/2 turn of the handle, the LOW part of the cam moves over the roller and stud in the feed arm, and the receipt feeding segment spring pulls the receipt feeding segment TOP to BACK until it is stopped by the receipt feeding adjusting plate. The receipt feeding segment is in mesh with the teeth on the receipt feeding plate (fig. 11-18) and turns the plate TOP to FRONT. Three paper feeding pawls (fig. 11-18) assembled on the receipt feeding plate are held against the teeth of the receiving roller ratchet by the feed pawl spring. As the receipt feeding plate turns TOP to FRONT, the pawls move over the teeth of the receiving roller ratchet and COCK the feed mechanism for SHORT feeding.

If the handle is turned 3/4 the distance around, the high part of the printer operating cam forces the front roller on the impression arm (fig. 11-16) to the front of the machine. The stud in the impression arm moves up but does NOT give any movement to the impression pitman, because the receipt impression feeler is on the INTERMEDIATE spots on the selecting plates.

One complete turn of the handle fully positions the type wheels; one and 1/4 turns of the handle position the HIGH part of the printer operating cam (fig. 11-17) under the back roller and stud on the impression arm and move it

UP in the back. The stud in the front of the arm moves DOWN and carries the receipt impression pitman along. The upper end of the pitman is connected to the receipt impression cam and oscillates it TOP to FRONT, and carries the amount impression rubber holder (fig. 11-16) DOWN against the type to print the amounts on the receipt paper.

Upon the completion of one and 3/4 turns of the handle, the rollers on the inside primer operating cam contact the feeler restoring plate (fig. 11-15) and move it TOP to FRONT to restore the impression feelers to their rest positions.

When the handle is turned one and 1/2 times, the high part of the printer operating cam moves tge feed arm DOWN in the back. On an item operation, however, the front of the feed arm does NOT contact the stud in the receipt feeding segment until the handle has been turned one and 7/8 turns, because the segment is stopped by the receipt feeding adjusting plate.

Upon the completion of one and 7/8 turns of the handle, the feed arm moves the receipt feeding segment TOP to FRONT. The segment then turns the receipt feeding plate TOP to BACK and the feed pawls turn the receiving roller ratchet and the receipt feeding gear TOP to BACK. The receipt feed gear, in mesh with the pinion on the receipt feeding roller (fig. 11-18), turns the roller TOP to FRONT. Gripped between the receipt feeding roller and the receipt pressure roller, the paper then feeds 1/4 inch.

The folowing discussion is for feeding and printing of the receipt paper on TOTAL and CASH 1 operations, with the ON-and-OFF lever in the ON position.

Operation of the receipt mechanism on all TOTAL and CASH 1 operations is similar to the operation for multiple-items. The only difference is that LOW spots in the selecting plates are placed over the receipt impression feeler (fig. 11-18) to allow the feeler to move TOP to FRONT far enough to place the SECOND working portion of the opening in the receipt impression pitman over the stud in the impression arm. This action sets up a condition for printing the date and the amounts on the receipt paper.

Low spots in the selecting plates also allow the receipt impression feeler to move DOWN far enough in the FRONT for both receipt feeding adjusting plates (fig. 11-18) to clear the tail of the receipt feeding segment. Downward movement of the receipt impression feeler permits the receipt feeding segment to move TOP to BACK until it is stopped by the receipt feeding stop plate (fig. 11-18), screwed to the left side frame, to cock the receipt feeding mechanism for LONG feeding.

During subtotal operations, a HIGH spot is over the receipt impression feeler and the receipt mechanism is disabled.

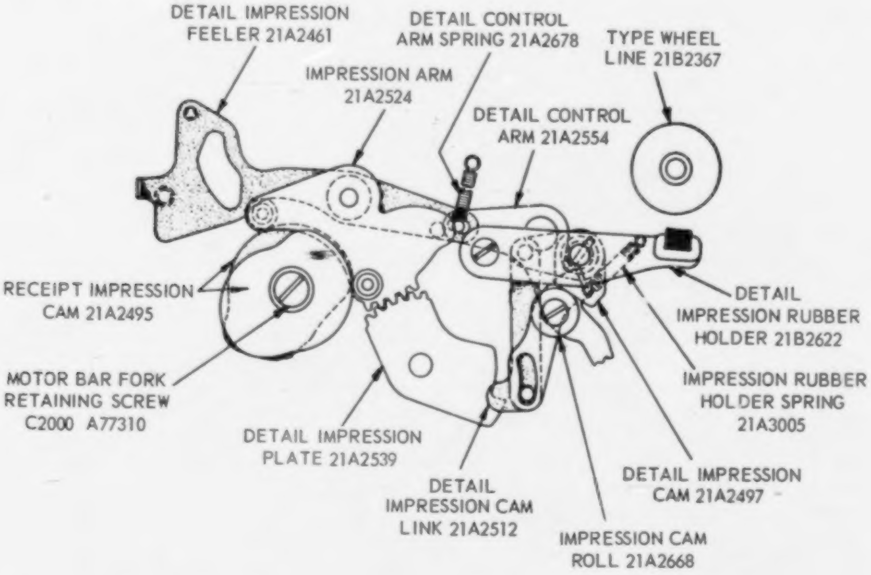
Detail Mechanism

The detail mechanism (figs. 11-19 and 11-20) on the Class 21 National cash register is constructed so that all items and their total, or just the total of the items, print on the detail strip (audit slip). For item printing on the detail stip, a LOW spot should be on the printer selecting plates under the detail impression feeler (fig. 11-19). If the total ONLY of the items is desired on the detail strip, a high spot should be under the detail impression feeler on item operations.

From HOME to 1/2 turn of the handle, the detail impression feeler is held away from the selecting plates in the same manner as the receipt impression feeler, so that the selecting plates can be positioned. Upon completion of a 1/2 turn of the handle, the rollers on the printer operating cam (fig. 11-19) move away from the feeler restoring plate (fig. 11-15) and spring tension pulls the plate from the top to the back of the machine. Another spring which pulls up on the front of the feeler carries it DOWN in the back to FEEL for high and low spots on the selecting plates.

If there are low spots under the receipt impression feeler, it moves down in the back and the front end raises the back extension of the detail control arm (fig. 11-19). The lower, front extension of the control arm is then moved far enough to the back to clear the hook on the detail feed stop pawl (fig. 11-19). The control arm also has an extension which yokes a stud in the detail impression cam link; and the arm moves the link to the back of the machine to place the stud in the link in the path of the step on the detail impression plate (fig. 11-20).

As the handle completes one and 1/4 turns, the impression arm in the back rises to turn the detail impression plate TOP to BACK. The step on the impression plate contacts the stud in the detail impression cam link and forces it up. The link is attached to the detail cam arm


DETAIL IMPRESSION FEELER 21A2461
DETAIL CONTROL ARM SPRING 21A2678
TYPE WHEEL LINE 21B2367
IMPRESSION ARM 21A2524
DETAIL CONTROL ARM 21A2554
RECEIPT IMPRESSION CAM 21A2495
DETAIL IMPRESSION RUBBER HOLDER 21B2622
MOTOR BAR FORK RETAINING SCREW C2000 A77310
IMPRESSION RUBBER HOLDER SPRING 21A3005
DETAIL IMPRESSION PLATE 21A2539
DETAIL IMPRESSION CAM 21A2497
DETAIL IMPRESSION CAM LINK 21A2512
IMPRESSION CAM ROLL 21A2668

91.417X

Figure 11-20. — Detail strip printing and feeding mechanism — Continued.

and the arm is turned TOP to FRONT. The detail cam arm is pinned to the right end of the detail cam shaft, and the shaft extends to the left through the two extensions of the detail impression rubber holder. The detail impression cam is pinned to the cam shaft between the extension of the impression rubber holder.

As the detail cam shaft turns TOP to FRONT, the high part of the detail impression cam (fig. 11-20) moves over the impression cam roller, which fits over a stationary stud in the back printer support plate. Movement of the high part of the cam over this roller causes the detail cam shaft to rise and the cam shaft to carry the detail impression rubber holder up to print on the detail strip.

As soon as the handle is turned one FULL turn, the low part of the printer operating cam moves over the roller on the feed arm and allows it to move down in front. Spring tension then turns the detail feed plate from TOP to BACK to cock the detail feeding mechanism.

At approximately one and 1/2 turns of the handle, the high part of the printer operating cam moves over the roller on the feed arm (fig. 11-19) and forces it down in the back. The front end of the feed arm then contacts the stud in the detail feed plate and turns it TOP to FRONT to space the detail.

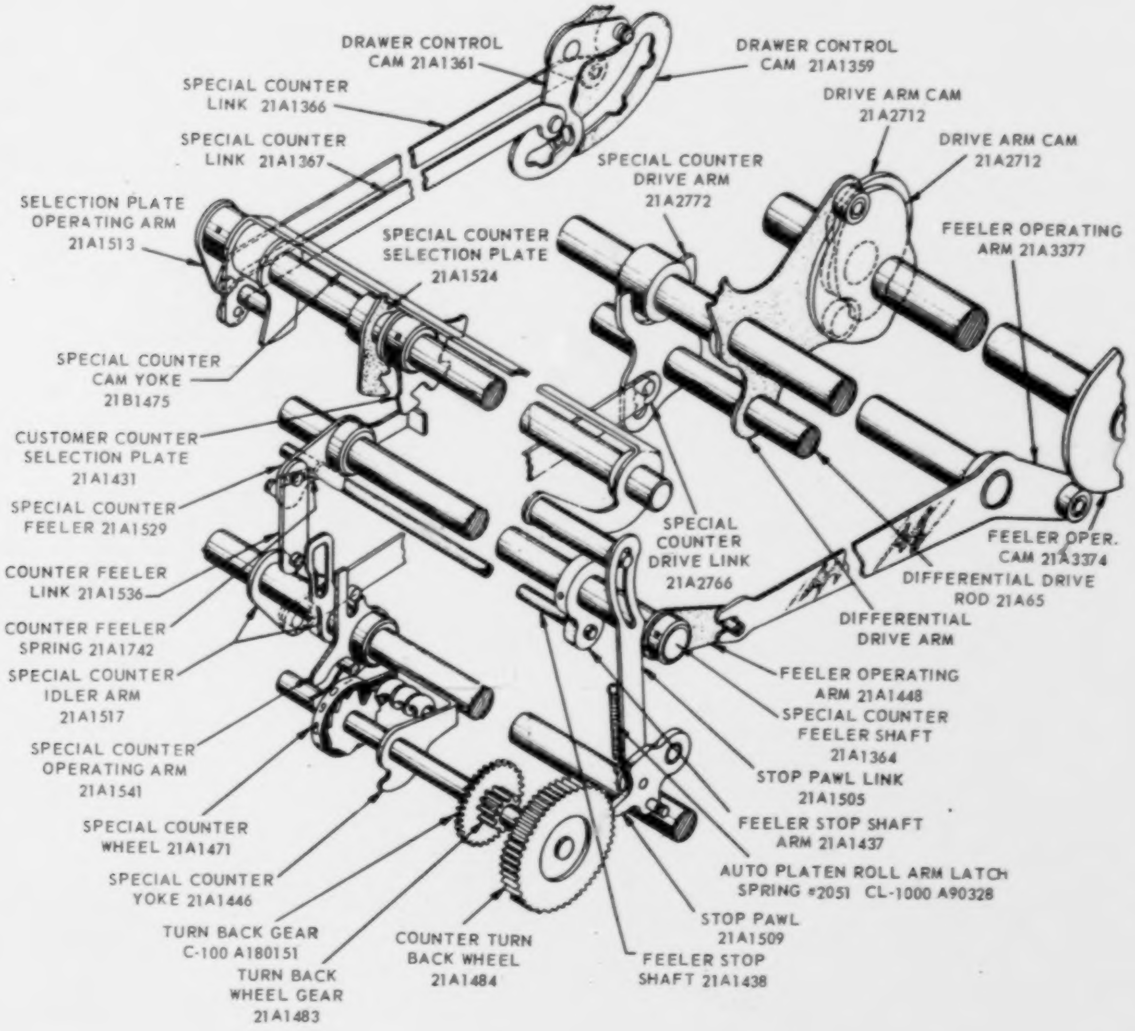
Special Counters

There is a special, a customer, and a reset counter in the Class 21 receipt printer for each key in ROW 2 (except subtotal key). Study figures 11-8 and 11-21. Each time the CASH 1 or the CASH TOTAL key is used the special counter marked CASH adds 1. All other keys in ROW 2 add on their own counters each time they are used when the control lock slide (fig. 11-13) is in the registering position.

The customer counter adds 1 each time a key in ROW 2 is used (subtotal, tax, and no-sale keys excluded). Special counters do NOT add during multiple-item operations.

With the exception of the reset counter, each special counter has a selecting plate (fig. 11-7) positioned by the transaction row which controls the selection of the counters when the control lock slide is in the registering position. A low spot in a selecting plate over one of the special counter feelers selects that counter to add; a high spot disables it.

The CASH, CUSTOMER, and CHARGE counters also have selecting plates positioned by the control lock slide. When the control lock slide is moved out of the registering position, these selecting plates place high spots over the special counter feelers to disable addition on the counters.


DRAWER CONTROL CAM 21A1361
DRAWER CONTROL CAM 21A1359
SPECIAL COUNTER LINK 21A1366
DRIVE ARM CAM 21A2712
SPECIAL COUNTER LINK 21A1367
DRIVE ARM CAM 21A2712
SPECIAL COUNTER DRIVE ARM 21A2772
SELECTION PLATE OPERATING ARM 21A1513
FEELER OPERATING ARM 21A3377
SPECIAL COUNTER SELECTION PLATE 21A1524
SPECIAL COUNTER CAM YOKE 21B1475
CUSTOMER COUNTER SELECTION PLATE 21A1431
SPECIAL COUNTER FEELER 21A1529
SPECIAL COUNTER DRIVE LINK 21A2766
FEELER OPER. CAM 21A3374
COUNTER FEELER LINK 21A1536
DIFFERENTIAL DRIVE ROD 21A65
COUNTER FEELER SPRING 21A1742
DIFFERENTIAL DRIVE ARM
SPECIAL COUNTER IDLER ARM 21A1517
FEELER OPERATING ARM 21A1448
SPECIAL COUNTER FEELER SHAFT 21A1364
SPECIAL COUNTER OPERATING ARM 21A1541
STOP PAWL LINK 21A1505
FEELER STOP SHAFT ARM 21A1437
SPECIAL COUNTER WHEEL 21A1471
AUTO PLATEN ROLL ARM LATCH SPRING #2051 CL-1000 A90328
SPECIAL COUNTER YOKE 21A1446
STOP PAWL 21A1509
TURN BACK GEAR C-100 A180151
COUNTER TURN BACK WHEEL 21A1484
FEELER STOP SHAFT 21A1438
TURN BACK WHEEL GEAR 21A1483

91.418X

Figure 11-21.—Special counter selection mechanism.

The reset counter is controlled by the control lock slide, and it adds one each time the register is operated with the control lock slide in the reset position.

The discussion which follows is for the selection of special counters from the TRANSACTION ROWS when the control lock slide is in the registering position.

Special counter link 21A1366 (fig. 11-21) is connected to drawer control cam 21A1359, which is positioned by the transaction row link arm line. The front end of the link is connected to the selection plate shaft (fig. 11-21). The special counter selection plates which control addition on the special counters when the control lock slide is in the registering position are pinned to the selection plate shaft, and they are positioned by the mechanism just described in such manner that a low spot is over the feeler of the special counter which corresponds to the key in use in row two.

A low spot in the selecting plate over the special counter feeler allows the feeler to move TOP to FRONT when the feeler stop shaft moves to the back as the handle is turned 1/2 turn.

The upper end of the counter feeler link (fig. 11-21) is attached to the front end of the special counter feeler, and the lower end of the link has a stud which extends to the right through an elongated hole in the special counter idler arm, and then over a DWELL in the special counter operating arm. As the special counter moves TOP to FRONT, the counter feeler link moves DOWN and the stud in the link enters the dwell in the special counter operating arm to set up a condition for that counter to add.

When a high spot on the selecting plate is positioned over the special counter feeler (fig. 11-21), the feeler cannot move TOP to FRONT far enough for the stud in the counter feeler link to enter the dwell in the special counter operating arm and the counter therefore does not add.

DISASSEMBLY

Disassembly of a Class 21 cash register is explained in the following paragraphs. Refer to applicable illustrations in this chapter as you study the procedure, step by step.

1. Remove the ribbon assembly and the lower printer support plate (fig. 11-9), NOTE; When you do this work in an instrument shop, refer to the manufacturer's technical manual for the machine.
2. Remove the feed roller support plate and the receipt feed roller.
3. Take off the receipt and detail supply roller hubs and the detail receiving roller.
4. Remove the printer unit by: (a) unhooking the back end of the type wheel drive segment links and pushing the links to the front, and (b) by removing the four screws which hold the unit to the left side frame.
5. Unhook the upper end of the link connected to printer selecting plate 21A2487. Remove the clip which holds the selecting plate on the stud and turn the selecting plate TOP to BACK until it clears the printer operating cam and then remove it.
6. Remove printer selecting plates 21A2164 and 21A2160 and the ON-and-OFF arm.
7. Remove the detail impression plate.
8. Remove the receipt feed gear, the receipt receiving roller ratchet, and the receipt feed plate. CAUTION: Protect the feed pawl springs.
9. Turn the handle of the register one and 1/2 turns and then remove the screw in the left end of the cam line. Hold the feed arm and the receipt impression feeler down in the back and remove the impression arm and the printer operating cam at the same time.
10. Remove the type wheel liner arm and the ribbon operating plate; then remove the detail impression feeler.
11. Slide the feed arm out slightly and remove the receipt feed segment and the detail control arm.
12. Remove the feed arm and the receipt impression pitman.
13. Take off the printer selecting plate (21A-2171) and the feeler restoring plate.
14. Unhook the spring on the detail paper feeler and turn the detail feed plate TOP to FRONT and remove the feeler.
15. Remove the detail receiving roller ratchet and the detail feeding plate.

The disassembly procedure for the printer unit is as follows:

1. Remove the detail impression rubber holder, the segment liner, and the roller release cam, in the order listed.
2. Unhook the springs and remove the spring shaft.
3. Remove screws from the printer support plate and the clip from the stud in the plate which holds the AMOUNT impression yoke. Then remove the printer support plate.
4. Remove the amount and date impression rubber holder and the date setting knobs.
5. Remove the electro and printer support plate (21A2129).
6. Take out the type wheels and the type wheel shafts (receipt and detail). NOTE: Keep type wheels on the shafts.
7. Remove the date wheels and their drive pinions, and then the type wheel drive segments.

To remove the special counters, do the following:

1. Remove the screws from the sides of the counter turn back shaft brackets. Then take out the trunnion from the left end of the counter turn back shaft, and remove the turn back wheel and gears. NOTE: Do NOT remove the pin from gear 21A180151. Slide the turn back shaft to the right, and also the trunnion on the right end of the shaft. Then operate the register until the special counter idler arms move to the back and remove the turn back shaft assembly.

2. Unhook and remove the reset counter feeler link.

3. Unhook the front end of the special counter drive link and slide the trunnion on the right end of the counter operating shaft to the left. then slide the entire shaft to the right and remove it.

4. Remove the trunnion on the right end of the special counter feeler shaft and take out the shaft.

5. Remove the trunnion on the right end of the selecting plate shaft and then remove the shaft.

NOTE: Reverse the disassembly procedure just described for rebuilding a special counter assembly.

REASSEMBLY

To reassemble a Class 21 cash register, proceed as follows:

1. Replace the detail feeding plate and the detail receiving roller ratchet.

2. Insert the detail paper feeler and hook the spring.

3. Install the feeler restoring plate and the printer selecting plate.

4. Replace the receipt impression feeler and the feed arm.

5. Insert the detail control arm and the receipt feeding segment.

6. Replace the detail impression feeler, the type wheel liner arm, and the ribbon operating plate, in order.

7. Install the receipt impression pitman.

8. Turn the handle one and 1/2 turns and replace the printer operating cam and the impression arm (at the same time).

9. Replace the detail impression plate, the ON-and-OFF arm, and the printer selecting plates.

10. Replace the printer unit. CAUTION: Be sure the stud in the ribbon feed operating link is back of the segment liner drive arm.

11. Replace all remaining parts of the machine. NOTE: When you replace the ribbon assembly, make certain that the stud on the ON-and-OFF yoke is in the elongated hole in the ON-and-OFF arm.

The procedure for rebuilding the printer unit follows:

1. Replace the type wheel drive segments.

2. Insert the date wheels and their drive pistons.

3. Install the printer support plate and put the timing rod through the type wheel drive segments.

4. Remove the detail type wheels from the type wheel shaft. Then start the type wheel shaft and the type wheel timing rod through the support plate and replace the type wheels one by one.

5. Replace the receipt type wheels in the same manner as you replaced the detail type wheels. NOTE: If you can insert a timing rod in all three receipt and detail type wheels and the type wheel drive segments as you reassemble them, they are in TIME.

6. Replace the detail impression rubber holder and the AMOUNT and DATE impression rubber holders.

7. Install printer support plate 21B2530 and the segment liner.

8. Replace the spring shaft and secure the springs.

9. Install the date setting knobs. CAUTION: Be certain the date on the printing line corresponds to the date indicated by the date setting knobs.

ADJUSTMENTS

Some of the adjustments you will be required to make on a Class 21 National cash register are:

1. Receipt feeding adjusting plate (21A2262). —Be sure that you have a clearance of 1/32 inch ONLY between the receipt feeding segment and the receipt feeding adjusting plate when it is in the rest position. TOO MUCH clearance allows the segment to cock the receipt feeding mechanism for SHORT feeding, even though a HIGH spot on the selecting plate was positioned over the receipt impression feeler. The small teeth on the receiving roller ratchet and the feeding pawls are responsible for such action.

2. Receipt feeding adjusting plate 21A2990. —Receipt feeding plate 21A2990 is properly adjusted when the receipt paper feeds 1/4 inch during multiple-item operations.

3. Receipt feeding stop plate 21A2261. — The receipt feeding stop plate is secured to the left side frame by screws and it stops the cocking movement of the receipt feeding segment on all LONG feeding operations. It is properly adjusted when the receipt paper feeds one and 7/8 inches on a single-item (CASH 1) operation.

4. Amount and electro impression rubber holders.—The receipt impression cam works on rollers in the amount and electro impression rubber holders. The rollers are assembled on eccentric studs, and you can increase or decrease the impression on the receipt by turning this stud (secured with set screw).

5. Receipt impression pitman.—The HOME position of the receipt impression pitman is determined by two impression pitman locating arms. So adjust the eccentric between the upper extensions of the arms so that the clearance between the edges of the opening in the pitman and the stud in the impression arm is equal above and below the stud when the receipt impression feeler is on a LOW spot in the selecting plates.

If you adjust the pitman in this manner, there is no likelihood that the corners of the opening in the pitman will catch on the stud in the impression arm when the pitman moves to the front of the machine.

6. Special counters.—The special counter drive arm has three adjustment positions, which feature enables you to adjust the amount of carry for the counter wheels. The stud in the special counter drive link is normally in the UPPER position. If more carry is required in the special counter wheels, move the stud to the MIDDLE or LOWER position, as required by the amount of additional carry necessary.

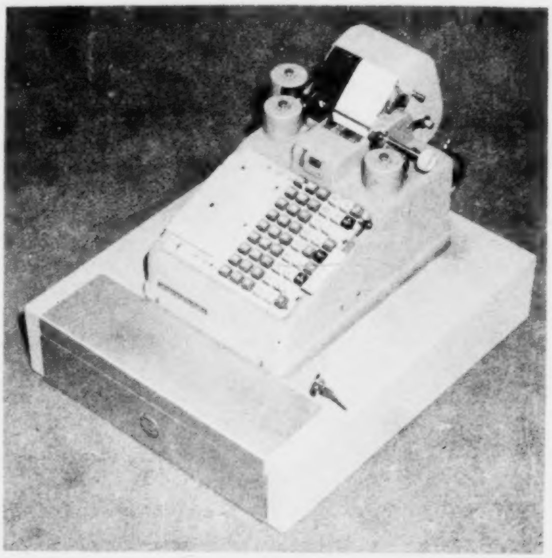
For additional information relative to adjustments of the Class 21 National cash register, or any other information, refer to the manufacturer's technical manual for the machine.

BURROUGHS CASH REGISTER

The Burroughs adding machine can be used as a cash register when converted as shown in figure 11-22. A Burroughs Series P100 or P300 adding machine mounted on a cash drawer and equipped with a paper rewind device makes a good general-purpose cash register. The P300 machine provides totals of individual sales for a specified period and a gross total of sales at the end of the period.

ADDING MACHINE DISASSEMBLY AND CLEANING

When adjusting, cleaning, or repairing an adding machine, be sure you disassemble the machine only to the extent required to accomplish the task. As with other office machines, adding machines should be disassembled in proper order and in accordance with instructions in the manufacturer's technical manual. You should have no difficulty in disassembling a specific machine if you follow the manufacturer's instructions. As you gain experience, disassembly will become easier.



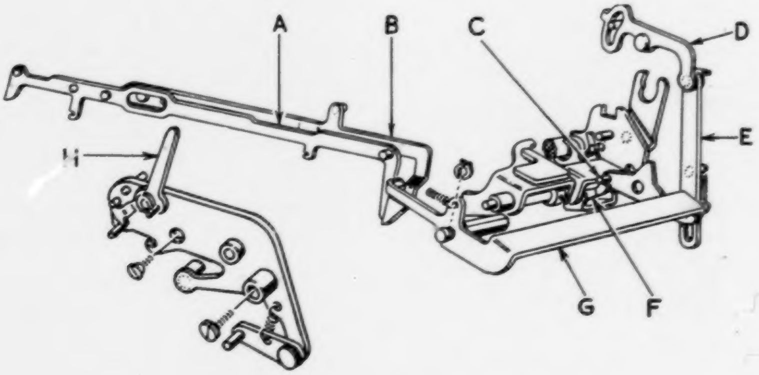
91.397X

Figure 11-22.—Burroughs cash register.

The cleaning process for adding machines is essentially the same as for typewriters. All parts which are not damaged by recommended solvents and cleaning solutions can be left on the machine when it is submerged in cleaning solution, or put in a cleaning machine. Electrical and rubber parts are damaged by cleaning agents and must NOT be put in solutions used for cleaning metal parts: Clean rubber parts with a clean cloth and denatured alcohol.

ADDING MACHINE ADJUSTMENTS

The following section describes adjustments to the Burroughs Series P400 adding machine. Before you continue, review the part of chapter 16, Instrumentman 3/2, which describes the mechanisms of this adding machine.



A. Slide to limit bail G (actuated by total key)
B. Slide to limit bail G (actuated by total and subtotal keys)
C. Stud on bail G
D. Space control arm
E. Space control link
F. Actuating arm for bail G
G. Bail
H. Jump total spacing lever

91.141X

Figure 11-23.—Form spacing mechanism.

FORM SPACING MECHANISM

The following adjustments of the form spacing mechanism are necessary to prevent 5/6" spacing:

1. When the jump total spacing lever H (fig. 11-23) is moved forward, its hooked portion should have minimum clearance under the lip of the space control arm D. To make proper adjustment, move or form the limit bail G.

2. When the machine is operating with the total key depressed and the jump total spacing lever H is in its forward position, the lip on the forward end of the space control arm D should have full hold on the hooked portion of the jump total spacing lever H. To adjust, bend the lip on the forward portion of the space control arm D.

To prevent 5/6" spacing during listing when the adjustable form space lever is in a position other than No. 5, make certain that the lip on the fore part of the limit bail G has minimum clearance over the step on the rear portions of the slides A and B actuated by the total key and the total and subtotal keys. To adjust, bend the front portion of the limit bail G.

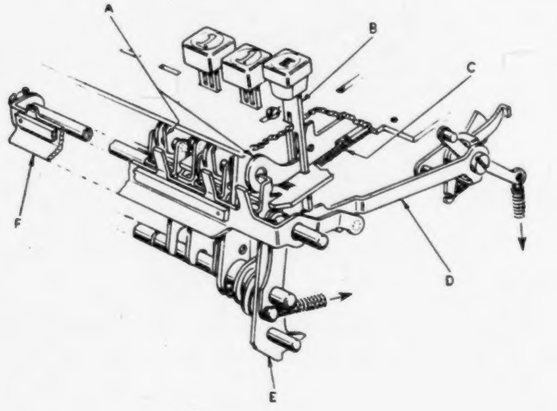
ERROR KEY MECHANISM

All keys should be free when you fully depress the error key (fig. 11-24). If adjustments are necessary for all columns, open or close the slot in the error arm D. To adjust individual columns, bend the upright projections on the key release bail.

The lips on the latching arm must clear the steps on the motor bars when the error key is fully depressed, to ensure release of the motor bars when the error key is depressed. To make proper adjustment, bend the upright projection on the right end of the key release bail F.

REPEAT KEY INTERLOCK

To ensure DISENGAGEMENT of latch I (fig. 11-25) from lip C, there should be a clearance of approximately .010" between lip C and the upper portion of latch I. You can make an adjustment to get this amount of clearance by bending the lowest part of latch I.



A. Locking strip
B. Error key stem
C. Key stem restorer spring
D. Error arm
E. Rocker arm controlling locking strip in column 0
F. Bail which releases keys from error key

91.142X
Figure 11-24.—Error key mechanism.

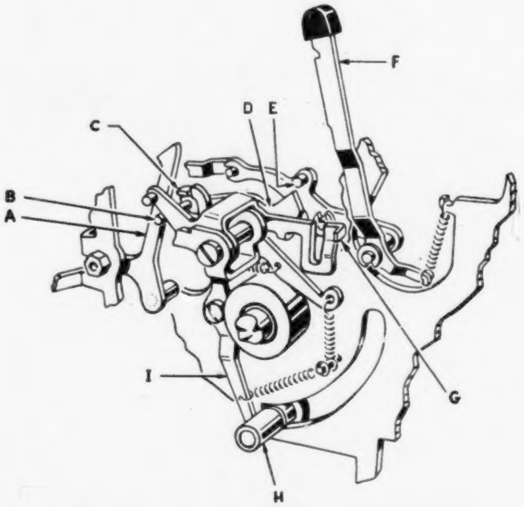
To ensure proper latching of the interlock E (fig. 11-26) there should be a clearance of approximately .010" between the lip of the interlock and the stop on the latch which limits the interlock. Bend the tail of the interlock TO or FROM the lip of the slide (F) to get the correct amount of clearance.

To ensure engagement of the interlock with the channel bail (J) (fig. 11-26) during a forward stroke (total key depressed), the latch (I) which limits the interlock (E) should be moved far enough by the stud on the segment arm to release the interlock and to permit it to engage the channel bail. To make proper adjustment, bend the inner tail of the latch which limits the interlock (E) to get earlier contact with the stud on the segment arm.

MOTOR BAR AND CONTROL KEY INTERLOCKS

Adjustments of the motor bar and control key interlocks are as follows:

1. To ensure actuation of the indexing mechanisms by the motor bars, B or E (fig.11-127) before tripping the clutch, the clutch should be tripped from slow depression of the minus bar B after it has been latched down by the lips W on the latching arm X. To adjust, bend the foremost finger on the intermediate motor bar F.

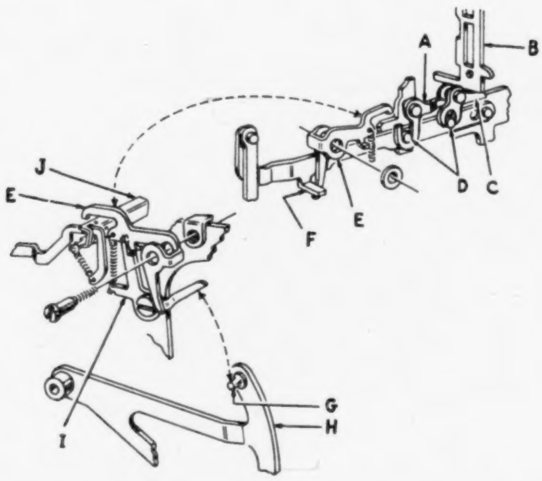


A. Repeat arm
B. Stud on arm D
C. Lip on arm D which is engaged by latch I
D. Arm which blocks travel of stud E
E. Stud which limits on arm D.
F. Register selector control lever
G. Lip which blocks forward movement of index bar in column 0
H. Roller on secondary mechanism
I. Latch which holds arm D in the raised position

91.143X
Figure 11-25.—Repeat key interlock.

2. To make certain that the indexing mechanisms are actuated by the operation control keys, before tripping the clutch, the clutch should be tripped from slow depression of specified operation control keys after the keys have been latched down. To make proper adjustment, bend the finger on the intermediate bar F which the operation control key contacts.

3. In order to safeguard against simultaneous depression of a motor bar and an operation control key, there should be a clearance of about .010"



A. Bellcrank which actuates slide F
B. Subtotal key stem
C. Bellcrank which actuates slide F
D. Stud on slide F
E. Interlock which blocks movement of channel bail J
F. Slide which controls interlock E
G. Stud on segment arm H
H. Segment arm
I. Latch which limits interlock E
J. Channel bail

91.144X
Figure 11-26. — Blocking of repeat total operations.

between the rear surface of the lowest portion of the motor bars (B & E) and the formed ears of interlock P when the motor bars are slowly depressed. To adjust, bend the U form on the rear portion of interlock P.

4. To avoid misoperation or a locked machine from a partial depression of the repeat key during plus operations, there should be a clearance at stud T on the key restoring arm over the upper point of the interlock (S) which limits rearward motion of stud T during a machine operation with either a motor bar or an operation control key latched down. To adjust, bend the forward portion of the arm Q which actuates the interlock.

5. To ensure release of the motor bars during machine operations, lips W (latches) on the latching arm X for plus and minus bars should be moved far enough forward to clear the steps on the motor bars when the machine is operated. To make proper adjustment, bend the lip on the forward portion of the latching arm.

SYMBOL INDEXING MECHANISMS

The following checks and adjustments of indexing mechanisms are important:

1. To ensure proper location of the adding rack in column 00 (to permit proper aligning shaft engagement when the register selector lever B (fig. 11-28) is in the AB position), the adding rack in column 00 should be so positioned that it permits the aligning shaft to move into the tooth spaces of the adding rack with minimum upward or downward movement of the adding rack. To get this type of adjustment, weave the upper right end of the adding rack.

2. To safeguard against the printing of a symbol in column 0 when the PLUS motor bar is depressed, there should be minimum clearance between lip M and projection N (fig. 11-29) when the plus motor bar is slowly depressed. To adjust properly, bend lip M.

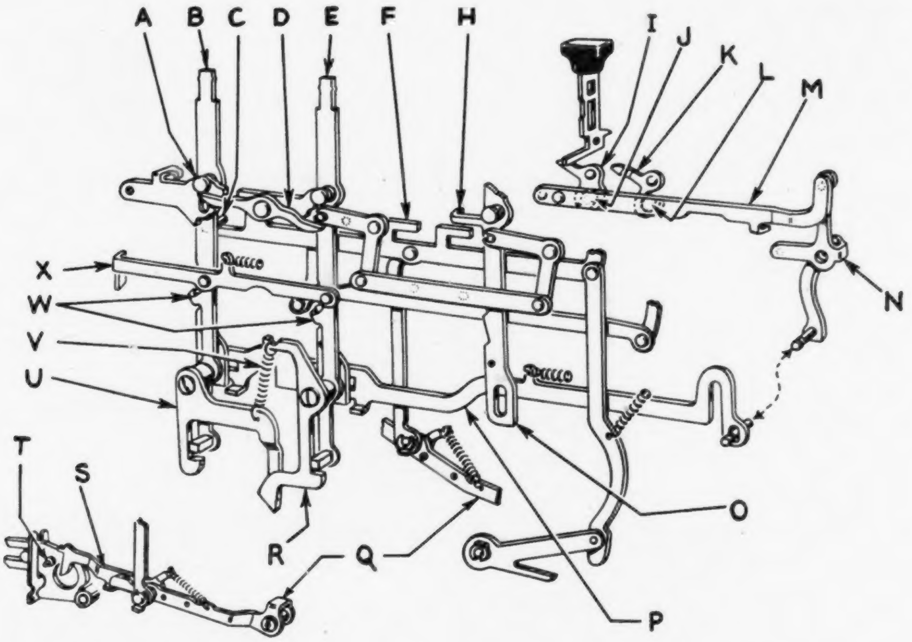
3. To prevent the printing of a symbol in column 0 during REPEAT-PLUS operations, there should be minimum (non-binding) clearance between lip Z (fig. 11-30) and projection Y when lip Z is manually raised. To adjust for proper clearance, spread or close the U slot in the arm which contains lip Z.

4. To ensure blocking of the index bar in column O when the repeat key is not fully depressed, the lower edge of lip Z (fig. 11-30) must be aligned FLUSH with the LOWER edge of projection Y when key stem W (fig. 11-30) is manually held depressed. To make this adjustment, bend lip Z up or down, as necessary.

5. To make certain that the forward movement of index bar E (fig. 11-31) is blocked by key stem AK, there must be minimum clearance, between the rear part of key AK and the front edge of projection AM when key AK is slowly depressed. To adjust, bend the lowest portion of key stem AK.

6. Projection AP (fig. 11-32) must have full lateral hold on key stem AO during the forward stroke of a plus total operation. Make proper adjustment by weaving the adding rack (column 0) up and down. This adjustment is necessary to get stoppage of the forward travel of the index bar F (column 0) during plus totals.

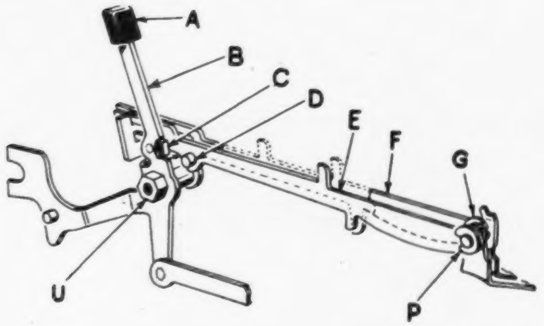
7. The adding rack in column O must be correctly located to permit proper aligning shaft



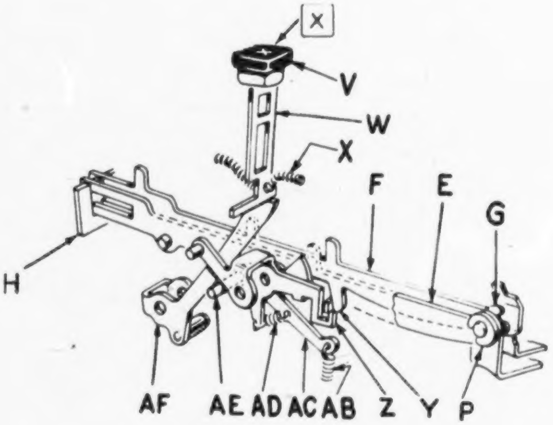
A. Stud on minus bar which actuates interlock D	O. Rear plus bar
B. Minus motor bar	P. Interlock which prevents depression of motor bars when total keys are depressed
C. Stud (on minus bar) which lowers the intermediate bar (F)	Q. Arm which actuates interlock S
D. Interlock which prevents simultaneous depression of plus and minus motor bars	R. Interlock which prevents snap depression of the plus bar during minus operations
E. Plus motor bar assembly	S. Interlock which limits rearward movement of stud T
F. Intermediate motor bar	T. Stud on key restoring arm
H. Lip (on motor bar assembly) which actuates intermediate bar F	U. Interlock which prevents snap depression of minus bar during plus operations
I. Bellcrank which actuates slide M	V. Spring which actuates interlocks R and U
J. Stud on slide M	W. Lips on latching arm X
K. Bellcrank which actuates slide M	X. Latching arm for plus and minus bars
L. Stud on slide M	
M. Slide which actuates link N	
N. Link connecting slide M and interlock P	

91.145X

Figure 11-27.—Motor bar and control key interlocks.



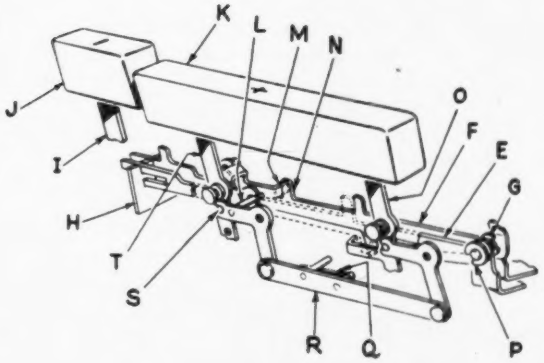
91.146X
Figure 11-28.—Register A and/or B accumulation.



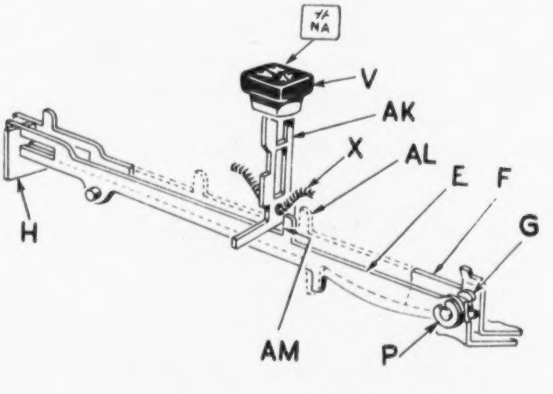
91.149X
Figure 11-30.—Prevention of symbol printing in column 0.

engagement during minus balance totals, with the machine in the minus balance position and during the forward stroke (total key depressed). To get proper location of this adding rack, tip AR (fig. 11-33) must limit travel of the adding rack to allow the aligning shaft to move into the tooth spaces of the rack with minimum upward or downward movement. To make proper adjustment, check slide AV for freedom of action and then bend lip AR forward or rearward, as necessary.

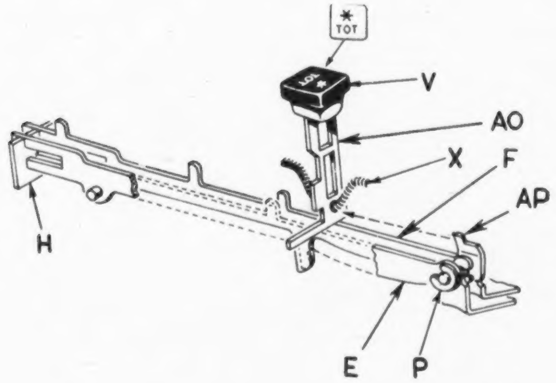
8. The adding rack in column 0 must also be correctly located to permit proper aligning shaft engagement during minus balance subtotals (machine in minus balance position, subtotal key depressed). Stud AW (fig. 11-34) must therefore limit the forward travel of slide AV as necessary in order to limit travel of the adding rack in column 0 to give the aligning shaft an opportunity to move into the tooth spaces of the adding rack with minimum upward or downward movement of the adding rack. Adjust by



91.147X
Figure 11-29.—Symbol index blocking by plus motor bar.



91.151X
Figure 11-31.—Action of non-add key on index bars in columns 0 and 00.

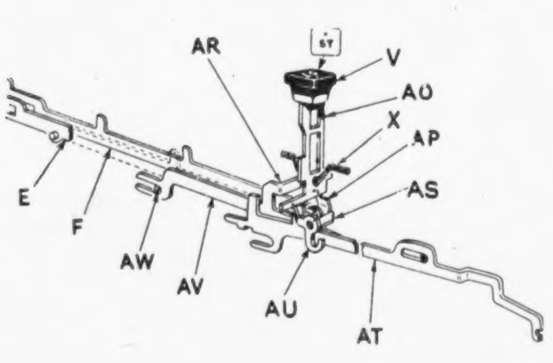


91.152X
Figure 11-32.—Limitation of index bar in column 0 by the total key.

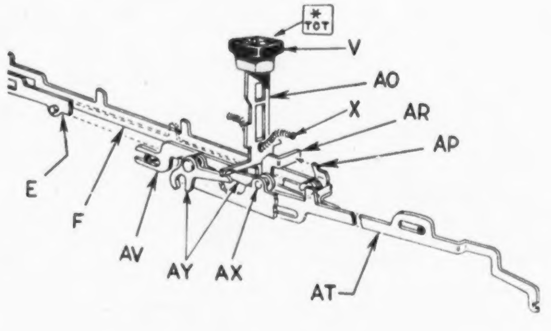
bending lip AR forward or rearward, as necessary, and then re-check for the condition stated in No. 7.

TOTAL KEYS INDEX HAMMERBLOCK MECHANISM

Make the following adjustment on the hammerlock mechanism (fig. 11-35): To ensure full movement of bail F when a total key is depressed, there should be minimum clearance between the lowest finger on bail J and the roll on the right end of bail F when either the total or subtotal key is latched depressed. To get proper clearance, bend the lip on bellcrank A.



91.154X
Figure 11-33.—Limitation of forward travel of index bar in column 0 by lip on slide AV.

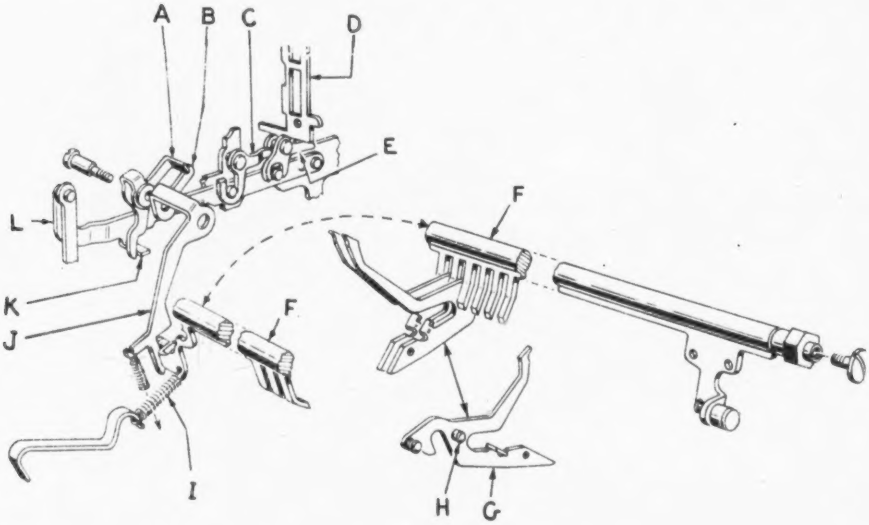


91.155X
Figure 11-34.—Control of travel of index bar in column 0 by slide AV.

INTERMEDIATE INDEXING MECHANISM

There are six tests and adjustments which you should make on the intermediate indexing mechanism (fig. 11-36):

1. In order that you may be able to get the correct starting point for making the next two adjustments, position the upright, right-angled arm of the retaining bail for guide S and limit plate L to its full limit toward the adding racks. Have the machine resting on the rear edges of the accumulating frames when you make this adjustment, by loosening screw N and positioning bail K.
2. Be sure that guide S limits against the left side frame, so that you will have correct alignment of the adding racks with the adding pinions. To make proper adjustments, loosen the two screws (M) and position the guide.
3. Make certain that plate L has a snug, non-binding limit against the lowest part of the adding racks when the handle is in the normal position. This limitation is essential to safeguard against a point-to-point lock of the adding pinions and the adding racks and tripping of carries when adding No. 9. Make proper adjustment by loosening the two screws (M) and positioning plate L.
4. Brace G must be held rigid in a fixed position. In order to hold it in this manner, bend the lips on its upper portion, as necessary.
5. To guard against excessive upward movement of the adding racks in columns 1 and 2, you must have a snug, non-binding fit between



A. Bellcrank which actuates bail J
B. Finger of bail J.
C. Bellcrank which actuates slide L
D. Total key stem.
E. Bellcrank which actuates slide L
F. Bail which indexes hammer latches (G)
G. Hammer latch

H. Roll on hammer latch
I. Spring which actuates bail F
J. Bail which holds bail F in normal position
K. Lip on slide L
L. Slide which actuates bellcrank A

91.157X

Figure 11-35. — Total keys index hammer block mechanism.

the fingers on brace G and the clips (A) which retain the index bars. Adjust as necessary by bending the fingers.

6. Prevent excessive upward movement of the adding racks in columns 8 through 13 by bending the fingers on brace C, as required, to get a snug, non-binding fit between the fingers on brace C and the No. 8 projections of the index bars, and also during the return stroke with the No. 9 listing keys indexed in columns 8 through 13. The No. 8 projections of the index bars must clear beneath the fingers on brace C to permit correct positioning of the cipher stops.

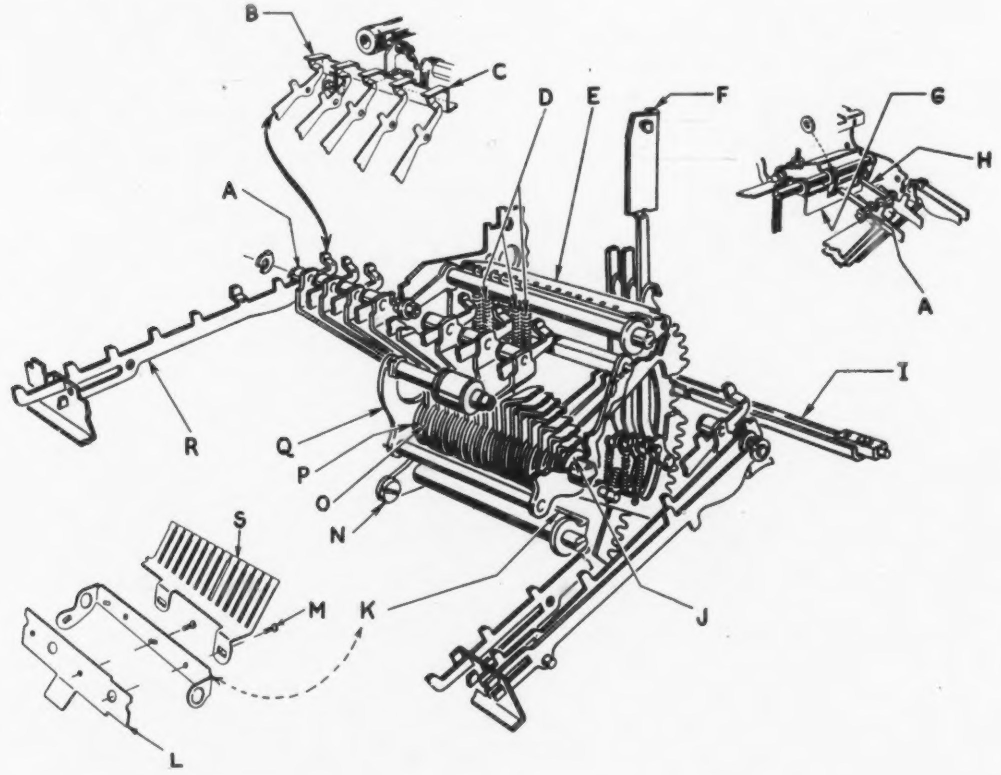
REGISTER SELECTOR MECHANISM

Adjustments on the register selector lever (fig. 11-37) are:

1. Align lever H (fig. 11-37) centrally in the slot of the upper keyboard plate, and see that it is free on bushing G. This adjustment can be made by bending lever H, and it is necessary to permit free movement of the register selector lever.

2. Bend the front portion of lever H up or down, as necessary, to ensure that the forked end of lever H is not in the path of the lower shaft of the key restoring rack assembly during the forward stroke of an operation (with lever H in any of the three operating positions). This adjustment prevents a handle break when the register selector lever is correctly located in any position, and also when it is partially shifted.

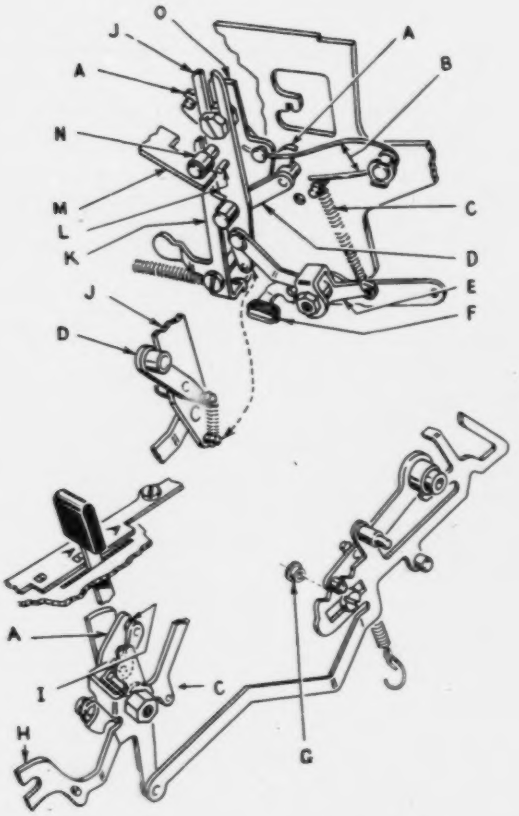
3. Bend the offset tail of latch K to get correct timing for the release of link assembly J. The offset tail of latch K should be aligned centrally with the foremost part of the dashpot actuating arm assembly. Latch K should also be moved from under stud L immediately after the full stroke pawl enters the first notch of the



A. Index bar (R) retaining clip
B. Finger on brace C
C. Brace which prevents excessive upward movement of adding racks
D. Adding rack springs
E. Limit bail for adding racks in the No. 9 position
F. Type bar
G. Brace which prevents excessive upward movement of adding racks
H. Finger on brace G
I. Guide for adding racks
J. Space collar
K. Bail which retains guide S and limits plate L
L. Plate which limits downward movement of adding racks
M. Screw which secures guide S
N. Screw which holds bail K to the left side frame
O. Space collar
P. Space collar
Q. Restoring frame
R. Index bar
S. Guide for adding racks

91.158X

Figure 11-36.—Intermediate indexing mechanism.



A. Pawl which reverses the position of the register selector lever
B. Spring which restores slide O
C. Spring which pulls arm F
D. Actuating pawl (A) arm
E. Arm which pulls link J
F. Cushioned limit for arm E
G. Bushing for register selector lever assembly
H. Register selector lever
I. Stud which connects the register selector to pawl A
J. Link which arm E actuates
K. Latch which prevents shifting of lever H during handle breaks
L. Limit stud for link J
M. Arm which restores link J
N. Roll
O. Slide which prevents automatic shifting of the register selector lever

91.159X

Figure 11-37.—Register selector mechanism.

full stroke segment during the forward stroke of a machine operation.

4. To safeguard against a false normal limit of the machine's main drive assembly, there must be a clearance of approximately .015" between roll N and arm M (fig. 11-37) when link J is held up manually. You can make proper adjustment by loosening the brace under arm M and bending arm M up or down. Then reposition the brace as required to get a snug fit to the underside of arm M.

5. In order to have equal alternating throw of the register selector lever, with the register selector lever control key released and the machine operated slowly during the return stroke, lever H should have equal alternating throw in the slot of the upper keyboard plate. Adjust by bending the upper arm of lever H to stud I.

6. Arm D should be so adjusted that it reverses positions. To adjust, loosen the two screws which retain limit arm F and raise or lower the back portion of arm F. Link J should have enough downward movement during the forward stroke of an operation to permit the roll on arm D to clear the bottom of slide O by about .010 inch.

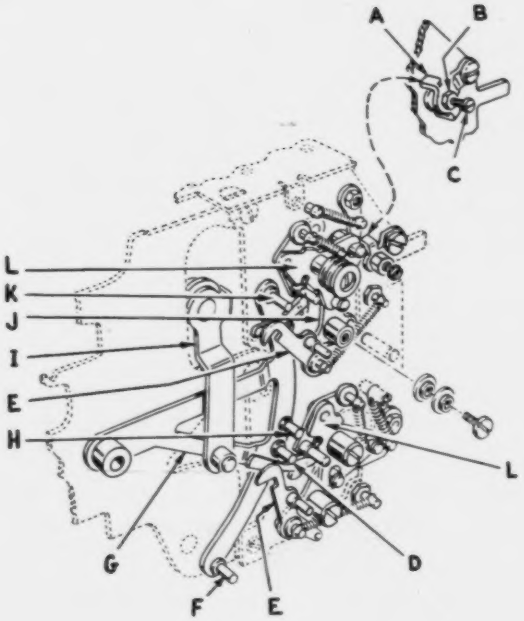
7. In order to ensure full resotration of slide O, it must move to its highest position when key AA is slowly released. Adjust slide O as necessary to give it freedom, and also check the condition of the slide restoration spring.

REGISTER MESHING CONTROLS

Make the following adjustments on the register meshing controls (fig. 11-38):

1. Check for a clearance of approximately .005" between stud K and the forward finger of the upper assembly, and also between stud D and the forward finger of the lower assembly. This amount of clearance is essential to prevent a false limit of segment G. To adjust properly, bend the forward fingers of the upper and lower assemblies, as necessary.

2. Test the lateral hold of studs K and D on the forward fingers of the upper and lower assemblies. During the return stroke of an operation, the hold of the studs on these fingers should be FULL in order to move registers A and B out of mesh (with lever AG in the AB position). Adjust as necessary by bending the forward fingers of the upper and lower assemblies.

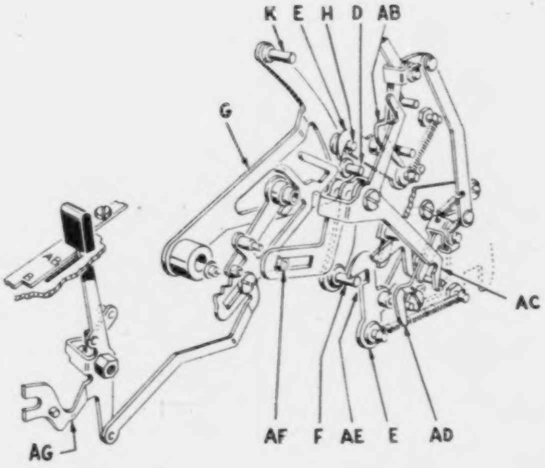


- A. Retainer for adjusting screw (C)
- B. Lock nut
- C. Adjusting screw
- D. Stud which moves register B out of mesh
- E. Listing pawls for registers A and B
- F. Stud which engages the lower pawl (E)
- G. Segment which controls registers A and B
- H. Stud which engages upper pawl F
- I. Link which connects segment G to the dashpot assembly
- J. Rocker arm which contains listing pawl (E) for register A
- K. Stud which moves register A out of mesh
- L. Rocker arm which contains the total pawl for register A

91.162X

Figure 11-38.—Register meshing controls.

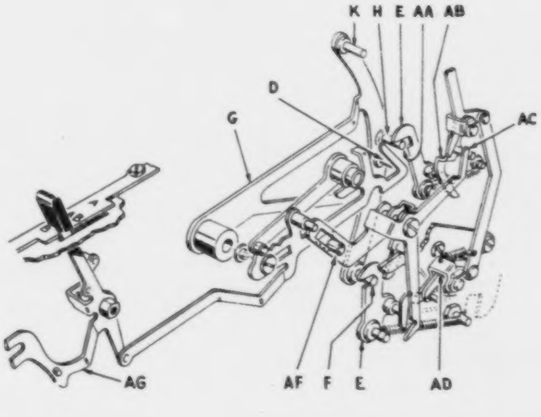
3. When lever AG is in the A position, there should be about 1/32" clearance between stud F and the lower pawl at point AE (fig. 11-39) as segment G moves downward during the return stroke of an operation. This amount of clearance is necessary in order to prevent the meshing of register A during a return stroke when lever AG is in the B position. Adjust by bending the lowest portion of arm AC.



91.163X

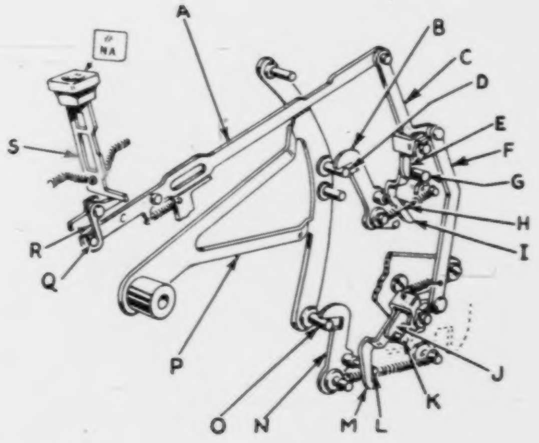
Figure 11-39.—Meshing and unmeshing of register A during a return stroke.

4. To safeguard against the meshing of register A during the return stroke of an operation when lever AG is in the B position, there should be a clearance of about 1/32" between stud H and the upper pawl at point AA (fig. 11-40) as segment G moves down during a return stroke. To get proper clearance, bend the uppermost finger of arm AC.



91.164X

Figure 11-40.—Meshing and unmeshing of register B during a return stroke.



A. Slide which actuates the rocker arm assembly
B. Listing pawl for register A
C. Rocker arm assembly
D. Stud which engages pawl B
E. Finger (on rocker arm assembly) which contacts stud G
F. Link on the rocker arm assembly (C)
G. Stud on arm I
H. Stud on listing pawl B
I. Arm which contacts stud H to raise pawl B
J. Finger on rocker arm assembly (C)
K. Stud on arm M
L. Stud on listing pawl N
M. Arm which raises listing pawl N
N. Listing pawl for register B
O. Stud (on segment P) which engages listing pawl N
P. Segment which controls register accumulators
Q. Stud which connects bellcrank R to slide A
R. Bellcrank which actuates slide A
S. Non-add key stem

91.166X

Figure 11-41.—Non-add mechanism.

NON-ADD MECHANISM

Tests and adjustments which you should make on the non-add mechanism (fig. 11-41) consist of the following: To prevent the adding of amounts in registers A and B during non-add operations, with the non-add key depressed, there should be no less than .010" clearance between stud D and pawl B (also between stud O and pawl N) as segment P moves downward during a return stroke. Make proper adjustment by bending the finger on the rocker arm (E) to increase the clearance between stud D and pawl B, and by bending finger J to increase the clearance between stud O and pawl N.

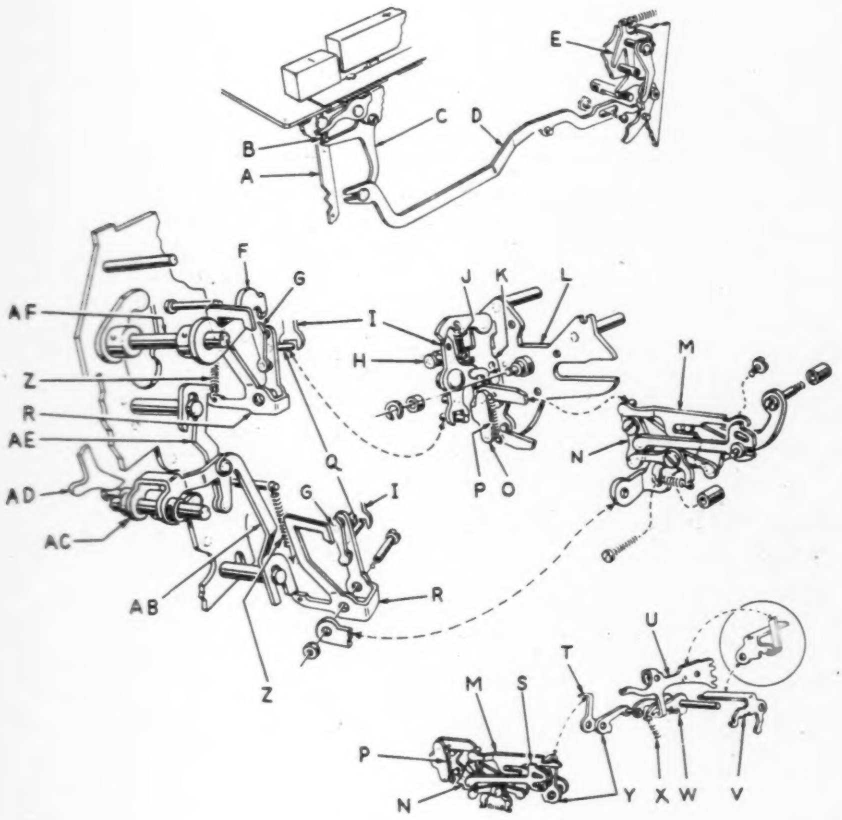
SUBTRACT MECHANISM

Make the following tests and adjustments on the subtract mechanism, as necessary:

1. Eliminate sideplay in the upper and lower shaft assemblies by loosening the lock nut (B, fig. 11-38), and turning the adjusting screw.
2. Bend the hooked parts of the bellcranks R (fig. 11-42) as necessary in order to get a clearance of about .010" with the left side of their rocker arms. Make this adjustment with the upper pinions in the ADD position, springs A unhooked, and studs Q held against the right side of the forked portion of arm I. This adjustment prevents partial shifting of the pinions when subtraction takes place.
3. With registers A and B in the ADD position, bend the lower arms of the bellcranks (R) as necessary to get a clearance of .005" of the bellcranks under links AB and AE when bail E is manually held completely rearward.
4. To ensure correct indexing of the subtract mechanism, bend the outward arm of bail E as necessary to have the high point of the camming portion of the bail on the center of the stud on assembly AC when the minus bar is depressed.
5. Adjust the forward edge of the inner arm bail (E) as required in order to have it limit against the post in the side frame when the minus motor bar is in the normal position. Adjust by bending the lower finger on the bellcrank which actuates bail E.
6. Bend the arms which rock the bellcranks (R) to the extent necessary to have equal clearance of the arms on either side of the spear points (G) when the adding pinions are fully meshed with the adding racks during the return stroke of minus and plus operations.

REGISTER CARRY MECHANISM

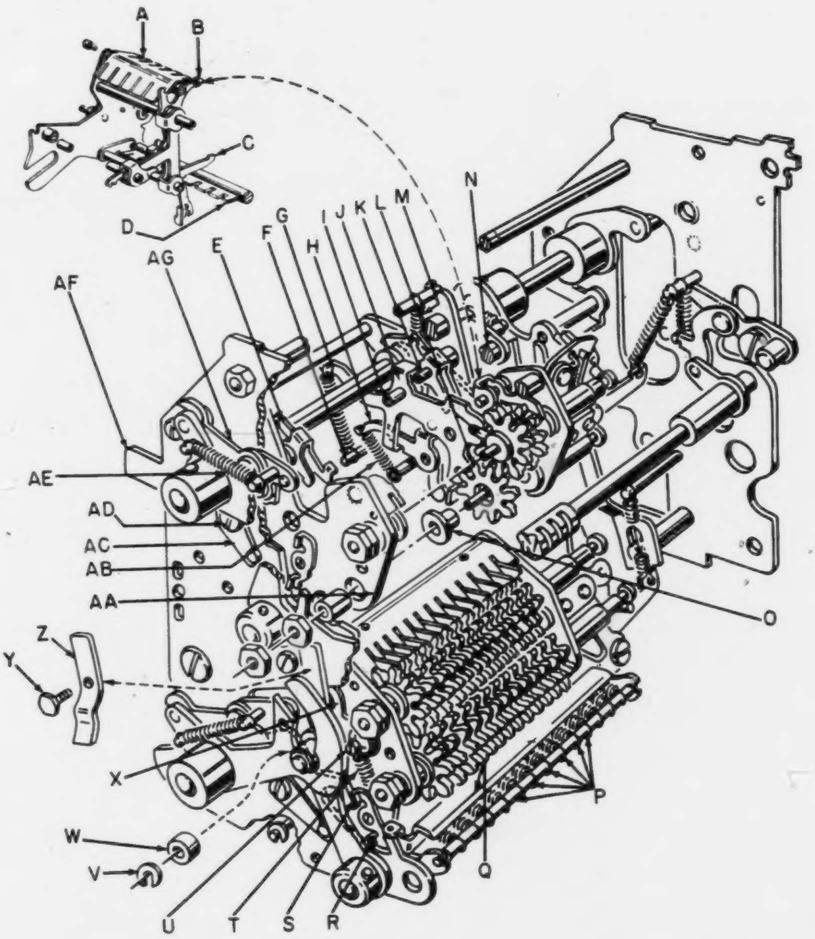
The following adjustments of the carry mechanism (fig. 11-43) of a Series P400 adding machine are essential:



A. Minus motor bar
B. Stud on minus bar which actuates bellcrank C
C. Bellcrank which connects minus bar A to subtract arm D
D. Subtract arm to actuating bail E
E. Bail which rocks assembly AC
F. Arm which rocks bellcrank R
G. Spear point finger assembled to bellcrank R
H. Adding pinion shaft
I. Rocker arm which shifts adding pinion shaft
J. Detent spring which holds rocker arm
K. Bracket
L. Right side plate of accumulator section
M. Link which rocks bail Y
N. Detent assembly which actuates links M and S
O. Lower part of bracket K
P. Spring which holds fingers on bracket K in position
Q. Stud to pivot rocker arms (I)
R. Bellcrank to pivot rocker arms
S. Link which rocks Bail Y
T. Lip on bail Y
U. Carry rack in column one
V. Automatic one carry bail
W. Carry rack latch in column one
X. Spring for latch W
Y. Bail which actuates latch W
Z. Spring which restores link assembly AB
AB. Link which actuates the lower bellcrank (R)
AC. Bail which actuates link AB
AD. Lower part of bail E
AE. Link which actuates the upper bellcrank
AF. Accumulator control shaft for register A

91.167X

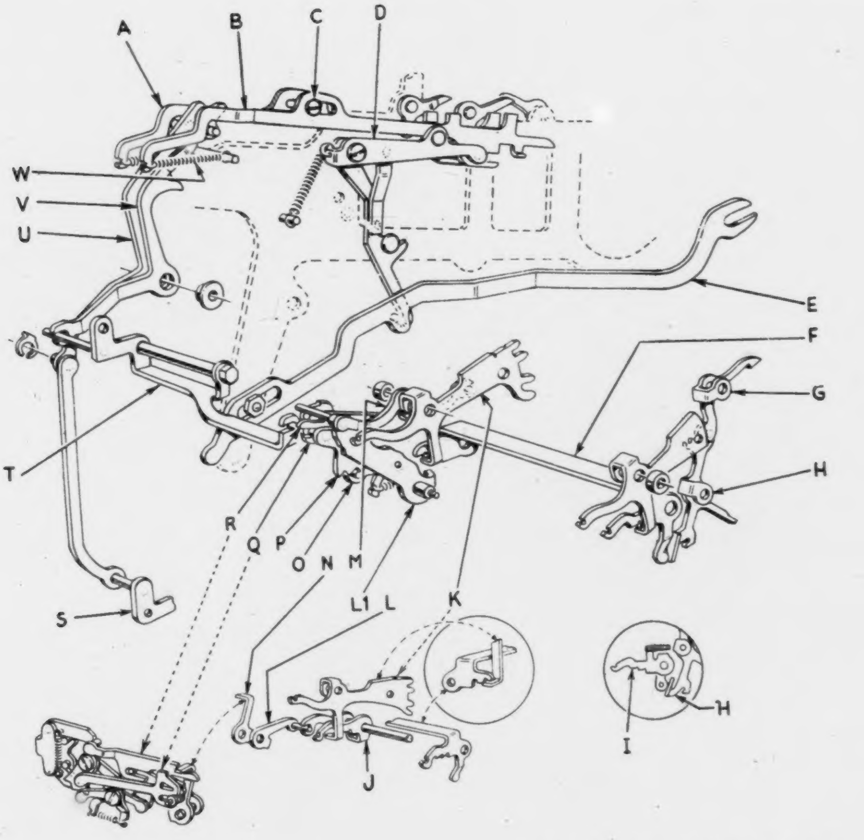
Figure 11-42.—Subtract mechanism.



A. Guide for carry pawl (upper)
B. Upper carry pawl
C. Lower carry pawl
D. Guide for lower carry pawl
E. Latch for carry pawl
F. Spring shaft
G. Carry rack spring
H. Carry rack latch
I. Carry rack retaining shaft
J. Carry rack
K. Shaft which retains carry pawl latches
L. Adding pinion
M. Spring for carry pawl latch
N. Carry rack reset shaft
O. Bushing for adding pinions
P. Lower carry pawl springs
Q. Bail which holds adding pinions in position when they mesh and unmesh
R. Lower lip on bail Q
S. Upper lip on bail Q
T. Spring which actuates bail Q
U. Spring anchor screw
V. Clip which holds roll W in position
W. Roll
X. Shaft retainer
Y. Screw
Z. Guide plate which prevents excessive side play in the accumulator section
AA. Left side plate of accumulator section
AB. Carry rack latch spring
AC. Shaft retainer
AD. Screw for shaft retainer
AE. Spring which holds link AG in position
AF. Left side frame
AG. Link on the carry rack reset shaft (N)

91.168X

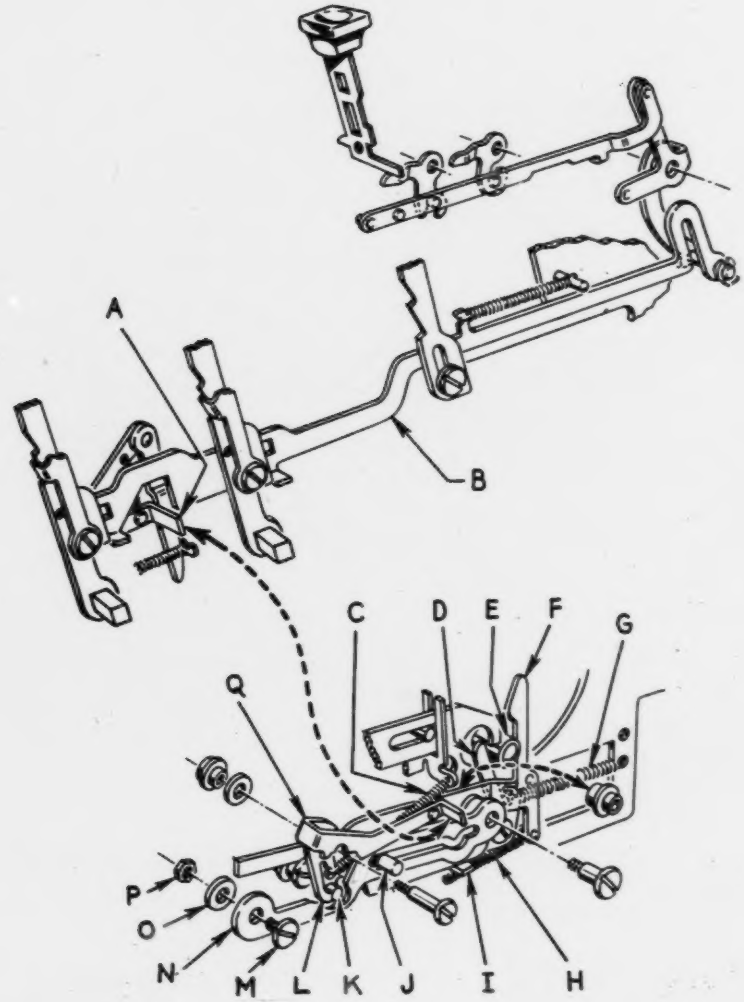
Figure 11-43.—Carry mechanism for registers A and B.



A. Minus balance total slide (register B)
B. Minus balance total slide (register A)
C. Screw which holds slide B
D. Bellcrank which actuates link E
E. Link to index subtract mechanism
F. Automatic one carry bail
G. Upper carry pawl
H. Lower carry pawl
I. Carry rack latch used in machines which have less than 13 columns
J. Carry rack latch in column one
K. Carry rack in column one
L. Bail which actuates latch J
L1. Brace
M. Arm which lowers links Q and R
N. Lip on bail L
O. Detent arm
P. Detent which holds links Q and R in position
Q. Link which rocks bail L
R. Link which rocks bail L
S. Bail which actuates slide A
T. Bail which actuates slide B
U. Arm which restores slide A to normal position
V. Arm which restores slide B to normal position
W. Spring which pulls slide B into the minus balance position

91.171X

Figure 11-44. — Minus balance mechanism.



A. Lip which blocks forward movement of interlock B	E. Roll on secondary mechanism	L. Tail on timing arm
B. Interlock which prevents simultaneous depression of total keys and motor bars	F. Timing slide to control timing arm	M. Screw which holds washer O and nut P
C. Spring which rocks timing arm (Q)	G. Spring on latch D	N. Timing arm which controls timing slide F
D. Latch which holds timing slide to the rear	H. Spring which restores slide F	O. Washer used for added weight to timing slide F
	I. Lip on latch D	P. Nut which holds washer on screw M
	J. Stud on slide F	Q. Timing arm which controls interlock B
	K. Stud on slide F which holds timing arm normal	

91.172X

Figure 11-45.—Total timing mechanism.

1. Bend the carry pawls (B) (fig. 11-43) as necessary to give them approximately .005" over-all side play, and then centrally align them in the slots of guide A.

2. Bend carry pawls C as required to give them about .005" over-all sideplay, and align them centrally in the slots of guide D. They must also be FREE on the studs in the upper pawls.

3. Open or close the U form of latches E to the extent required to keep sideplay at .010 inch. This amount of sideplay ensures correct normal and initial carry positions for pawls B and C.

4. To ensure free movement and proper alignment of the carry racks, make certain that their sideplay is not over .010 inch.

5. Open or close the U form of latches H to give them between .010" and .015" of sideplay. These latches must have proper alignment and freedom of movement.

6. The upper and lower adding pinions must have FREE movement in order that they may spin. When their bushings become worn and interfere with movement, replace them.

7. Weave the bail which holds the adding pinions in position as required to safeguard against a point-to-point locking of the adding pinions with either the adding or carrying racks.

8. Bend the lips of the bail which holds the adding pinions in position to the extent necessary to give the upper edge of the bail about .010" clearance below the point of the teeth of the lower pinions when they are meshed with either the adding or carrying racks.

9. As a precaution against over and under additions, bend the lip on the lowest part of the lower carry pawl to ensure NOT LESS THAN .008" and NO MORE THAN .012" clearance between the lip on the lowest part of the lower pawl and the lower leg of the carry rack latch, when the accumulator is in its normal position.

MINUS BALANCE MECHANISM

Adjustments on the minus balance mechanism (fig. 11-44) as follows:

1. Weave bail F as necessary to have the steps on its right and left ends parallel to the lips on the carry rack in the first and last columns.

2. Weave bails S and/or T to the extent required to have a clearance of .010" between the front ends of the slots in slides A and B and the stud containing screw C when the stud in detent arm O is seated in the rear pocket of detent P.

3. Bend the forked portion of latch J as necessary to give it a safe hold on the stud of bail L. This adjustment is necessary in order to have latch J raised in preparation of an automatic one.

4. To ensure maximum upward travel of carry rack K, tilt the stud on the rear part of arm M as required to get a clearance of approximately .010" between the stud and its rear portion and brace L1 and carry rack K moves up into a carried position.

TOTAL TIMING MECHANISM

Tests and adjustments for the total timing mechanism (fig. 11-45) are as follows:

1. To prevent lip A's interference with the normal forward movement of slide B, bend tail L to or from stud K to the extent necessary to get a clearance of about .010" between the upper edge of lip A and the lower edge of slide B after slide B moves forward from a depression of either total key.

2. Lip A must block forward movement of slide B in order to block the result keys. Lip A should have normal binding clearance with the forward edge of the step in slide B when arm Q is raised or lowered manually. To adjust, bend lip A.

3. Bend finger D TO or FROM roll E, as necessary, to safeguard against premature depression of the total keys. When the machine is normal, there should be a clearance of approximately .005" between lip I and the lower edge of slide F.

APPENDIX I
REPORT OF CALIBRATION FOR DEADWEIGHT TESTER

DEPARTMENT OF THE NAVY
U. S. NAVAL WEAPONS QUALITY ASSURANCE OFFICE
WASHINGTON, D.C. - 20390

Navy Standards Laboratory
Report of Calibration

FOR

DEAD WEIGHT TESTER

SUBMITTED BY:

Manufacturer: Amthor Testing Instrument Company, Brooklyn, New York
Mfr Model No: 472-10M
Mfr Ser No : 10572

Range: 100 to 10,000 PSI Nominal Piston Size: 0.0123 sq. in.

The attached discussion of errors of dead weight gage testers supplements this report.

Mass of Weights and Piston(s): The weights have been weighed with the results given in Table I. The values given are on the ordinary commercial basis of apparent mass, as determined in air, against brass standards; therefore, in calculating air buoyancy corrections the weights should be assumed to have a density of 8.4g/cm^3. The tabulated values are correct to one part in 10,000.

Effective Area: The effective area of each piston and cylinder combination was determined by direct comparison with one of the Eastern Standards Laboratory piston gages. The two gages were connected together and the weight load on the standard was adjusted to achieve a balance. Measurements were made at selected pressures throughout the range of the test instrument. The effective area (A_e) of the combination of piston and cylinder maybe expressed by an empirical relationship of the form $A_e = A_o + BP$ where A_o is the effective area at zero pressure, and B represents the change of area with pressure as a result of elastic distortion.

AMBIENT TEMP 20°C
RELATIVE HUMIDITY 45%
REPORT NO. M-0003-A & N
DATE 20 October 1971
NDW-QAO-4355/64 (1-65)

PREPARED BY: ____________________
APPROVED BY: ____________________
RESUBMISSION DATE

DEAD WEIGHT TESTER
Mfr Model No. 472-10K
Mfr Ser No. 10572

If the area is measured in square inches, the nominal pressure (P) in psi then the values of A_o and B which best fit the results of the test are:

A_o = **0.0123626 sq. in.**

B = **3.5×10^{-10} sq. in./PSI**

The reported area is the effective area at 20°C. The effective area at other temperatures may be calculated as indicated in the attached discussion of errors. The determination of effective area is correct to one part in 10,000.

The resolution of the gage, i.e. the change in pressure from equilibrium which will cause the piston to rise or fall, was:

0.0018 PSI throughout the range.

When using the tester considerable care should be taken in leveling the instrument to reduce friction to a minimum, and corrections for buoyancy, fluid head, temperature and gravity determined and applied as required.

Standards used by the Eastern Standards Laboratory are traceable to standards maintained by the National Bureau of Standards or by the U. S. Navy.

DEAD WEIGHT TESTER
Model No: 472-10K
Serial No: 10572

P.S.I.	Pc.No.	Apparent Mass vs Brass Pounds
1000	1	12.3725
1000	2	12.3719
1000	3	12.3724
1000	4	12.3722
1000	5	12.3724
1000	6	12.3724
1000	7	12.3723
1000	8	12.3724
1000	9	12.3725
400	1	4.9488
200	1	2.4743
100	1	1.23712
100	2	1.23700
50	1	0.61816
50	2	0.61814
100	Piston	1.23705

SUPPLEMENT TO REPORTS OF CALIBRATION
FOR
DEAD WEIGHT PISTON GAGES

Supplement to Reports of Calibration

for

Dead Weight Piston Gages

1. INTRODUCTION

2. PRESSURE

3. FORCE

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    3.2 Mass of the Air (air buoyancy)
    3.3 Mass of the Fluid (fluid buoyancy)
    3.4 Gravity
    3.5 Surface Tension

4. AREA

    4.1 Effective Area at Atmospheric Pressure
    4.2 Temperature Coefficient of Area
    4.3 Pressure Coefficient of Area
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5. FLUID HEAD

6. FACTORS AFFECTING PERFORMANCE

    6.1 Eccentric Load Error
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    6.3 Liquid Buoyancy
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    6.6 Friction
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    6.9 Fluid Viscosity
    6.10 Leaks
    6.11 Line Restriction

7. PRESSURE EQUATION

8. CONCLUSION AND ACKNOWLEDGEMENT

Appendix I—REPORT OF CALIBRATION FOR DEADWEIGHT TESTER

1. INTRODUCTION

The dead weight piston gage (also known as "dead weight gage", "dead weight tester", "gage tester", "pressure balance" or "piston manometer") is one of the few instruments that can be used to measure pressure in terms of the fundamental units, force and area. In principle, it is a piston inserted into a close fitting cylinder. Weights loaded on one end of the piston are supported by fluid pressure applied to the other end. Construction of piston gages varies as to method of loading, methods of rotating or oscillating the piston to reduce friction, and design of the piston and cylinder. Three designs of cylinders are commonly used; the simple cylinder with atmospheric pressure on the outside; the re-entrant cylinder with the test pressure applied to the outside as well as the inside; and the controlled clearance cylinder with an external jacket in which hydraulic pressure can be applied so as to vary the clearance between the piston and cylinder at will of the operator. In order to use the piston gage for the measurement of pressure, one must take into account a number of parameters of the instrument and its environment.

Error in measurement results from failure to account for the parameters or from the uncertainty of the measured values of them. It is obvious that error results from the uncertainty of the mass of the loading weights and the measurement of the effective area of the piston and cylinder.

Other sources of error perhaps not so readily apparent include the effect of air buoyancy on the weights, fluid buoyancy on the piston, the value of local gravity, the force on the piston due to surface tension of the fluid, the thermal expansion and elastic deformation of the piston and cylinder, and the fluid heads. These effects can be evaluated and corrections applied to reduce the magnitude of overall error of the measurement. All of these factors will not necessarily be applicable in every measurement. The importance of each depends upon the design of the instrument, the environment, and the application. For example, if a piston gage is used in work for which an accuracy of one-half of one percent is adequate the nominal pressure (sum of the denominations of the weights loading the piston) may be taken as correct. However, the same gage, if of good design and maintained in good condition, is capable of measuring pressures with much higher accuracies (to 1 part in 10,000 or better) by use of good operating technique and application of proper corrections.

2. PRESSURE

The pressure in any system may be defined as $P = \frac{F}{A}$, where F = force and

A = area over which the force is applied. When a piston gage is in equilibrium with a pressure system the pressure, P_p, measured at the piston gage reference level is $P_p = \frac{F_e}{A_e}$ where F_e = the force due to the load on the piston and A_e = the effective area of the piston gage. The reference level is the level at the bottom of the piston, whereas the pressure to be measured may be at another level within a system connected to the piston gage by a length of tubing filled with a pressure transmitting fluid. Correction must therefore be made for the pressure difference due to the head of fluid between these points. If the total (absolute) pressure is to be determined the atmospheric pressure at the reference level of the piston gage must be added to the piston gage pressure. Usually the pressure to be determined is the difference between the total internal pressure of the system and the atmospheric pressure outside the system. If the pressure is to be measured at a level in the system markedly different from the reference level of the piston gage correction for the difference in atmospheric pressure at these levels must be applied (air head).

3. FORCE

There are several quantities that must be accounted for in the determination of the force (F_e) acting upon the effective area of the piston. These include the mass of the weights and piston, the mass of the air displaced by the load, and the mass of the pressure fluid contributing to the load, the local acceleration due to gravity, and the force due to surface tension of the pressure fluid acting upon the circumference of the piston where it emerges from the fluid.

3.1 Mass of the Weights

The mass of the weights, including the piston and all parts which contribute to the load on the piston when in operation is determined by the Mass Laboratory of the ESL as apparent mass versus brass standards. Therefore the weights should be assumed to have the same density as the brass standards (8.4 grams/cm^3)

The uncertainty quoted in the Report of Calibration includes an allowance for possible instability of the values which may occur between calibrations.

3.2 Mass of the Air (air buoyancy correction)

The mass of air displaced by the load on the piston is the product of the density of the air and the volume of the load. The volume of the load should be computed from its density and this factor is in turn dependent on the manner in which the values of the loading weights are reported. If reported in true mass values then the actual density of the weights should be used. If reported as apparent mass, as is customarily the case, then weights should be assumed to have the same density as the brass standards. If the design of the gage permits the pressure fluid to contribute to the load on the piston an air buoyancy correction for the fluid contributing to the load should also be calculated for the most precise work.

The density of the air at room temperature and sea level pressure is very nearly .0012 grams/cm^3. Under these conditions the mass of the loading weights will be reduced approximately one part in seven thousand.

3.3 Mass of the Fluid (fluid buoyancy)

In certain instances the pressure fluid in which the piston is immersed contributes to the load on the piston. This fluid buoyancy correction may be either positive or negative. In practice the effective area of a piston gage is very nearly that of the mean of the cross sectional areas of the piston and the cylinder. Any metal extending beyond these limits displaces a volume of fluid whose mass must be subtracted from the load on the piston and the mass of any fluid within these limits must be added to the load on the piston. This effect may be accounted for in either of two ways. One method is to compute the mass of the fluid contributing to the load and include it in the calculation of the force acting on the area. Alternatively, the reference level (level at which the piston gage pressure is measured) may be shifted up or down from the lower end of the piston by an amount equal to the height of a column of fluid that will compensate for the mass of the fluid acting on the piston. Computation of the mass of the fluid requires knowledge of its density. For the portion of the piston between the top of the cylinder and the free fluid surface the density will be that of the fluid at atmospheric pressure. However, for the portion of the piston below the cylinder the density will be that of the fluid when subjected to the measured pressure, P_p, and may not be easily determined. The problem is simplified if the buoyancy correction for the upper part of the piston is applied as a load correction and that for the lower part of the piston as a reference level change. The height of the reference level with respect to the lower end of the piston then becomes the difference between the actual length of the piston below the cylinder and the length of a piston of uniform cross section of A_o and equal volume. When the actual cross section is larger than A_o the reference level is below the lower end of the piston and when it is smaller than A_o the reference level is above the lower end of the piston.

3.4 Gravity

The pressure developed by a dead weight piston gage is proportional to the local value of gravity. If the latitude, ϕ, and the elevation above sea level, a, (in feet) are known for the station, the absolute value of local gravity, g, in cm/sec^2 is given approximately by the formula:

$$g = 980.616 - 2.5862 \cos 2\phi + .0058 \cos^2 2\phi - .000094\, a$$

Due to local anomalies the value of gravity at any location may differ substantially from that of the formula. Deviations in excess of 0.100 cm/sec^2 have been observed in some sections of the United States. For the greatest accuracy, gravitymeter observations can be made on site by a survey team from the U. S. Coast and Geodetic Survey, the U. S. Geological Survey or a private geophysical organization.

The arbitrary standard for gravity, although differing from the most recent determination by nearly 0.05 cm/sec^2, has been established by extensive use to be 980.665 cm/sec^2 at sea level and 45° latitude. Therefore the force (weight load) acting on the piston can be obtained by multiplying the apparent mass by the factor:

$$\left(\frac{\text{Local Gravity}}{\text{Standard Gravity}}\right) \qquad \left(1 - \frac{\text{Air Density}}{\text{Brass Density}}\right)$$

Using the value of .0012 grams/cm^3 for the density of the air, 8.4 grams/cm^3 for the density of brass, and 980.665 cm/sec^2 as the gravitational constant the force is equal to 0.980525 times the product of the apparent mass and the local value for gravity.

3.5 Surface Tension

The pressure correction due to surface tension is usually negligible, but may amount to more than 0.005 psi. The magnitude of the correction in pounds per square inch may be calculated from the surface tension of the fluid (pounds-force/inch) times the circumference of the piston (inches) divided by the area (square inches).

For a typical piston gage of 10,000 psi range, with a simple piston of A_o = .0125 square inches which develops a minimum pressure of 100 psi nominal and operated with aviation instrument oil as the pressure fluid, the pressure equivalent of the surface tension is .0054 psi ($.00017 \times .396331 \div .0125$). Thus this effect varies from .005% at minimum pressure to .00005% at maximum pressure.

4. AREA

For a dead weight piston gage connected to a tight system so that the piston is falling slowly because of the leakage of fluid past it, the effective area approximates the average of the cross section areas of the piston and the bore of cylinder. The effective area is affected by temperature and by the elastic distortion of the piston and cylinder when pressure is applied.

4.1 Effective Area at Atmospheric Pressure

The effective area at the reference temperature and atmospheric pressure may be calculated from direct measurements of the diameters of the piston and cylinder, or by comparison with a piston gage whose parameters are known.

4.2 Temperature Coefficient of Area

The fractional change in effective area per unit change in temperature is equal to the sum of the thermal coefficients of linear expansion of the piston and cylinder. The temperature of the piston and cylinder at working pressure is usually assumed to be the same as that at the instrument base, or more conveniently, the average temperature of the laboratory in which the instrument is used. In fact, the piston and cylinder are usually at a somewhat higher temperature than the rest of the instrument, but so many factors affect the actual temperature that calculation of the temperature rise is unreliable. Uncertainty in t can be kept within acceptable limits if the precaution is taken to keep the speed of rotation no greater than is necessary to maintain lubrication (60 to 120 RPM).

4.3 Pressure Coefficient of Area

The distortion of the piston and cylinder under pressure depends greatly on the design and materials and may either increase or decrease the effective area by as much as a part in a thousand at ten thousand pounds per square inch.

The direct measurement of some pistons and most cylinders is difficult to do with adequate accuracy, and calculations of the pressure coefficient are usually unreliable. It is, however, possible to balance a piston gage against another with high precision, and when the area and pressure coefficient of one are known the area and pressure coefficient of the other can be determined. The usual method used to calibrate piston gages, and the procedure employed at the ESL, is to weigh the load and then determine the values for area, and change in area with pressure by the balancing (cross-floating) method.

4.4 Area Coefficients for Controlled Clearance Gages

The pressure coefficient of area for controlled clearance piston gages is determined from the elastic properties of the piston by a theoretical relationship of Poisson's ratio and Young's modulus. The fractional change in effective area with unit change in jacket pressure can be determined experimentally by varying the jacket pressure and measuring the resultant small change in measured pressure, P_p. The jacket pressure necessary to reduce the clearance between the piston and cylinder to zero is usually determined from fall rate data. The sensitivity of the instrumentation required for these determinations is such as to make the measurements practical only at the higher echelon laboratories. Refer to the Report of Calibration for these values.

5. FLUID HEAD

One correction which must always be considered when using a dead weight piston gage, not inherent in the gage but arising from the test configuration, is that of a fluid head. It usually happens that the gage being tested or the point at which the pressure is to be determined is not at the reference level of the piston gage. A correction must therefore be made for the pressure difference due to the head of fluid between these points. When oil is used as the pressure fluid the correction will be approximately 0.03 psi per inch of difference in the levels.

The magnitude of the correction may be determined from:

$$\Delta P = \rho_f hkg_1$$

where ρ_f = density of the fluid

h = vertical height of the fluid column measured from the reference level of the piston gage

k = proportionality constant for standard gravity

g_1 = local acceleration due to gravity

and ΔP = the pressure difference (in pounds per square inch when ρ_f is in pounds per cubic inch and h is in inches).

When the point at which the pressure is to be determined is above the piston gage reference level the pressure at that point will be less than that sensed by the piston gage, (P_p is reduced by ΔP) and when the test point is below the reference level of the piston gage the pressure will be greater than P_p.

With large values of h, or when measurement of low pressures with high precision is required an additional correction for the air head (difference in atmospheric pressure between the piston gage reference level and the test point) may be required.

Under normal laboratory conditions the air head corrections is approximately .00004 psi per inch of difference in the levels. With a ratio of 750 to 1 for the effect of oil versus air head it is obvious that for most work the air head correction may be ignored when liquid media are used as the pressure transmitting fluids.

6. FACTORS AFFECTING PERFORMANCE

The performance of dead weight loaded piston gages should not limit the accuracy of measurements made with the instrument. At low pressures the uncertainty of the value of the area A_0 is usually the limitation, and at high pressures the uncertainty in the value of the pressure coefficient of area b, may be the limitation. The reproducibility of a piston gage in good working condition should be better than one part in twenty thousand in order to achieve the greatest possible accuracy.

6.1 Eccentric Load Error

Erratic behavior has sometimes been observed if the weights are stacked off center. The "eccentric load error" is the most common cause of poor performance of piston gages. Errors in the pressure exceeding one part in a thousand have been observed. The magnitude of eccentric load error has been observed to be a function of the speed, but not the direction of rotation of the weights, and depends on the eccentricity and magnitude of the load, the alignment of the piston, cylinder, and guide bearing and the clearance between the piston and cylinder and in the guide bearing, and the leveling of the instrument.

Design of the weights are an important consideration in reducing eccentric load error. The diameter should be large, so that the height of the stack does not exceed the diameter. Individual weights should be balanced and should nest or index on the piston so that the load is balanced.

Some techniques for reducing eccentric load error are as follows:

1. Level the piston gage so that the piston rotates about a vertical axis. This is done by placing a bubble level on the piston and adjusting the instrument so that the piston and bubble level can be rotated together to any position without any change in indication.
2. Stack the weights so that they are centered on the axis of rotation.
3. Avoid excessive speed of rotation.

6.2 Corkscrewing

A helical scratch or tool mark on the piston, cylinder or guide bearing of a piston gage may result in an error known as "corkscrewing". This is a function of the speed and direction of rotation of the piston. It is usually negligible, but in severe cases may amount to as much as one part in a thousand. Corkscrew error can be reduced by avoiding excessive rotational speed. The user should not fall into the habit of making all observations with the piston rotating in one direction. About half of the observations should be made with the piston rotating in each direction. The observer will than be in a position to notice the corkscrew error if it appears. He can, if he wishes, average readings taken with the two directions of rotation.

6.3 Liquid Buoyancy

The buoyancy of the pressure transmitting liquid acting upon the piston assembly can be accounted for if it is constant and not too large. In some cases the secondary guide piston passes through a cavity that may be partially or entirely filled with liquid. As the piston moves up and down and the oil level lowers and rises, the effect of buoyancy may vary from zero to as much as 0.5 psi. Use of a piston gage having variable buoyancy necessitates a technique whereby the buoyancy can be made reproducible and known.

6.4 Drive Error

There are numerous ways by which the piston may be driven in a rotational or oscillatory manner. Nearly all methods may impart a vertical component of force to the piston. This vertical component will be proportional to the torque required to drive the piston and will be a function of load, speed, friction, and level. The resultant error may be negligible or may be very large. One test to determine the magnitude of drive error is to compare the results obtained with the drive in operation, with the results obtained when the piston and load are coasting free from the drive. A suspended, non-rotating load may oscillate abnormally when the piston is rotated or oscillated at a particular speed. Such speeds should be avoided.

6.5 Weights

The weights should be nonmagnetic, solid, and preferably of a hard, nonporous metal, such as brass or stainless steel. The surface finish should be smooth, preferably polished. Other considerations such as balance, diameter, and indexing are discussed above in connection with eccentric load effect.

6.6 Friction

Friction in a piston gage reduces the sensitivity and reproducibility of the instrument to a marked degree. Excessive friction results from eccentric loading, improper leveling, misalignment of the piston-cylinder-guide bearing assembly and either excessive or insufficient clearance between the piston and cylinder. Friction in the bearing between the piston and yoke of a suspended, nonrotating load may also be excessive.

When the weights are loaded on the piston and set into rotation, they should continue to rotate for several minutes. The simplest and most revealing criteria of performance is the coasting time of a freely spinning loaded piston!

6.7 Fall Rate

When the piston gage is connected to a leak tight system and the piston set into rotation, the piston will fall slowly as a result of the leak between it and the cylinder. The rate of fall will depend upon the clearance, length of crevice, diameter of the piston, pressure, viscosity of the fluid and concentricity of the piston and cylinder. Re-entrant cylinder piston gages should have their maximum fall rate at a pressure about one half of the range. Simple cylinder piston gages usually have fall rates which increase with pressure. However, at very high pressures most pressure fluids exhibit a very rapid increase in viscosity with pressure so that the fall rate may not increase as rapidly as expected. (A fall rate of 1/10 on an inch per minute is indicative of a poor quality gage and one likely to be unreliable for even routine pressure measurements.)

6.8 Aging Effects

A dimensional change of the piston or cylinder which affects the effective area significantly will be accompanied by a large change in the rate of leak of fluid between the piston and cylinder. The leak may be measured by observing the rate of fall of the piston when the gage is connected to a tight system of small volume.

6.9 Fluid Viscosity

The effective area of the piston is not affected by the viscosity of the pressure fluids, but the sensitivity, fall rate, and wear rate are affected by the viscosity. The best viscosity is one that will be high enough for a reasonable fall rate but not so high as to make the spin time too short and cause sluggish operation.

6.10 Leaks

Leaks other than that between the piston and cylinder, may result in pressure drop in connecting lines or in excessive fall rate either of which might result in significant measurement error.

6.11 Line Restriction

Long or small diameter connecting lines or other restrictions may result in significant pressure drop when leaks are present. Ordinarily small diameter lines are not objectionable when the piston gage is connected to a tight closed system. When two piston gages are to be balanced against each other a restriction between them may result in slow insensitive operation. This nearly always is true when oil is used to transmit the pressure. An air lubricated piston gage connected to a large volume system or to another air lubricated piston gage may oscillate between the piston stops. The oscillations can be reduced by introducing a restriction in the line to obtain sufficient damping of the system so that a balance can be achieved.

7. PRESSURE EQUATION

The pressure developed by a dead weight piston gage is given by:

$$P_p = \frac{\dfrac{M_m}{A_o}\left(1 - \dfrac{\rho a}{\rho m}\right) kg_1 + \dfrac{M_f}{A_o}\left(1 - \dfrac{\rho a}{\rho f}\right) kg_1 + \dfrac{\gamma C}{A_o}}{\left[1 + a\,(t-t_s)\right]\,(1 + bP_p)\,\left[1 + d(P_{zo} + S_z P_p - P_j)\right]}$$

where the reference level is determined as discussed in paragraph 3.3.

In the above equation:

P_p = The pressure at the reference level in pounds per square inch.

M_m = The apparent mass of the loading weights, including the piston assembly, in pounds.

A_o = The effective area at atmospheric pressure and temperature t_s.

ρ_a = The mean density of the air displaced by the load in grams per cubic centimeter.

ρ_m = The density of the loading weight (8.4 grams per cubic centimeter for M_m in apparent mass).

M_f = Mass of the pressure fluid contributing to the load on the piston.

ρ_f = The density of the pressure fluid at atmospheric pressure in grams per cubic centimeter.

k = The proportionality constant for standard gravity = $\frac{1}{980.665}$

g_1 = The local acceleration due to gravity in cm/sec^2.

γ = The surface tension of the pressure fluid.

C = The circumference of the piston at the surface of the pressure fluid.

a = The fractional change in area per degree C (equal to the sum of the thermal coefficients of linear expansion of the piston and cylinder).

t = The temperature of the piston gage in degrees C.

t_s = The temperature, in degrees C, at which the value of A_o is known.

b = The fractional change in area per unit change in pressure.

d = The fractional change in area per unit change in jacket pressure.

P_{zo} = The jacket pressure required to reduce the piston/cylinder clearance to zero when $P_p = 0$.

S_z = Rate of change of zero clearance jacket pressure with measured pressure.

P_j = The jacket pressure.

The above equation, although not rigorously exact, is adequate for pressure measurements within the Navy Calibration Program. Solving it for each pressure measurement could prove unnecessarily laborious, however, terms may be grouped to reduce calculations to reasonable proportions, and some terms may be eliminated in consonance with the required precision of the measurement.

The importance of each factor and term depends on the design of the instrument, the environment, and the application, and none should be eliminated without an evaluation to determine its significance.

8. CONCLUSION AND ACKNOWLEDGEMENT

This supplement is intended to present a practical discussion of the factors which affect the measurement of pressure with a dead weight piston gage. A detailed technical discussion is contained in NBS Monograph 65, "Reduction of Data for Piston Gage Pressure Measurements". The material in this supplement has been freely adapted from Monograph 65, other unpublished sources, and combined with several years of practical experience in the calibration of piston gages at the ESL.

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